HANDBOOK OF FIELD AND OFFICE PROBLEMS IN FOREST MENSURATION

BY

HUGO WINKENWERDER

Dean, College of Forestry, University of Washington

AND

ELIAS T. CLARK

Associate Professor of Forestry, University of Washington

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PREFACE

The problems in this handbook were originally prepared as an aid to the laboratory instruction in forest mensuration at the University of Washington, and were first published by the authors in 1915. Numerous changes and additions were made in this edition, particularly with reference to making them more generally useful to the practical field and office men and more generally applicable to all sections of the country. In the few instances where they are not applicable they can readily be made so by slight modifications at the instance of the instructor in charge.

In each problem the forms for recording and for working up the data have been definitely indicated. It has been found that this will result in greater uniformity and better standards of comparison for the work of the individual students. Although different schools are using forms that differ in some of the details they can readily be made applicable by adopting form numbers to coincide with those adopted in this handbook. These forms are illustrated in the Appendix on pages 90 to 97.

In the preparation of the handbook the object has not been to present a complete series of problems covering the entire field of forest mensuration, but rather a series of carefully selected *type* exercises which may be used as practical illustrations to supplement the recitation and text-book work. A number of the newer methods recently developed but not yet thoroughly established have been purposely omitted. References to various new methods will be found in the Appendix, in connection with the *Bibliography*. The authors have included only problems of standard character.

It is hoped that the value of the handbook will be due as much to what is omitted as to what is actually included. Experience has shown that a few fundamental type exercises, carefully worked out in the field and laboratory, and their relation to associated problems then brought out in class-room discussions will give the student a more thorough grounding in the subject than a multitude of exercises hurriedly worked over but not assimilated.

A second feature sought in these problems is the elimination of an undue amount of duplication in clerical work. The function of a university is to teach the how and the wherefore. Our time is too limited to use more than a reasonable amount of it for drill work, and it has been our experience that clerical drudgery often obscures the fundamental object of an exercise. Though a student works over only a limited number of data in the field or laboratory this is no excuse for

an instructor to allow the student to gain a false impression concerning the actual number of data required in an extensive investigation.

A third object sought is a thorough correlation of the individual fundamental problems in forest mensuration and to show their relation to the larger problems which are usually dependent upon a combination of the fundamentals. It has been sought to accomplish this by keeping the fundamental problems wholly distinct from each other in the early exercises. This should serve to prevent obscuring their broad field of usefulness for other purposes. In the succeeding exercises the fundamental problems have, however, been combined with the more extensive ones so as to coordinate them and to emphasize their special relationships. The directions for the fundamental problems are also given in considerable detail; in the succeeding problems, however, wherein the former are used only as a step in the solution, the student is made to depend upon his knowledge of the methods outlined in preceding problems by having the directions in the latter made more general.

Nearly all of these problems have been used in about their present form by the students at the University of Washington. Only such changes have been made as were necessary to bring the manuscript up to date and otherwise put it in proper form for publication.

Although the majority of forest schools now have their work so arranged that in connection with the field work they can obtain data for the greater part of the office problems, every locality does not contain the conditions that would furnish the proper kind of data for all of them. For this reason data have been supplied for use in connection with all of the office problems presented. However, in order to keep the price of the book within reasonable limits it has been necessary to limit the quantity of these data included. Though they are therefore not adapted for extensive practice it is hoped they may be of considerable help for illustrative purposes. Wherever these data are supplied in any limited quantity, a special effort was made to select them with reference to average conditions but not so as to destroy their general illustrative value. That the data are only in a few cases presented on the complete field forms should not detract from their value, but should rather help the student to remember just what measurements are required for a certain problem.

The authors wish to acknowledge their indebtedness to Mr. Bror L. Gröndal, of the College of Forestry, University of Washington, and Mr. T. T. Munger and Mr. L. A. Nelson, both of District 6, United States Forest Service, Portland, Oregon, and to the instructors in other Forest Schools who have used the "Exercises" for helpful suggestions.

Hugo Winkenwerder.
Elias T. Clark.

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FIELD AND OFFICE PROBLEMS IN FOREST MENSURATION

SECTION I—PRELIMINARY MEASUREMENTS

PROBLEM 1. (Field.) PACING.

EXPLANATION.—A great deal of the work in forest mensuration requires accurate pacing. The student should therefore at the outset learn to establish a distance of a surveyor's chain or mile with a fair degree of accuracy. In learning to pace the student should use his ordinary walking step. A longer step may be used with accuracy for short distances but cannot be kept up in long distance pacing without fatigue.

DIRECTIONS.

A. *Parties.*—Each man will do individual work in this problem.

B. *Equipment Required.*

1 hand compass.
1 100-foot steel tape.
1 field note book supplied with Form 1.

C. *Method of Procedure.*

1. With the aid of another member of the class carefully lay off a quarter mile course over fairly rough country with a steel tape and a hand compass.
2. Go over the course several times using your ordinary step in order to determine how many double paces you take to cover the course. Then adjust the number of paces you take to the quarter mile to a certain even number which can readily be broken up into chains and rods; *i.e.*, 240, 250, 260, etc. After establishing a standard step, go over the course repeatedly until you can cover the distance with practically the exact number of your standard paces. You should not be satisfied until your limit of error is within 3 double paces.

NOTE.—In practically all engineering and mensuration work the distance between two points is expressed in terms of horizontal distance. Therefore in pacing across broken country the horizontal distance must be secured. Where the topography is rolling this may be accomplished by slightly lengthening the step, but where the slopes are steep resort should be made to one of the following expedients:

a. Take extra steps to secure the unit pace.

b. With a jacob staff or a stick lay off the pace horizontally on the ground.

c. Estimate the distances in terms of some unit of distance, *i.e.*, pace rod, or chain.

. When you can pace the original course satisfactorily, lay off a distance of a quarter of a mile in some other direction by means of pacing and a hand compass. During the actual process of pacing make a rough plat to a suitable scale of the physical features such as woods, trails, creeks, fences, etc., of the country you cross and note on the plat the distance in feet of each from the starting point. Draw the plat on Form 1 of the Field Note Book.

4. Check the accuracy of your pacing. With the aid of another member of the class go over the course covered in 3 above with compass and steel tape and note on the plat the exact measured distances from the starting point to each of the physical features indicated.

D. *References.*—Consult table of units of measure in Appendix.

PROBLEM 2. (Field) THE DETERMINATION OF THE DIAMETERS OF STANDING TREES.

EXPLANATION.—The object of this exercise is to give practice in estimating the diameters of trees by eye, to show the use of different types of instruments, and to compare the efficiency of the different methods in use

DIRECTIONS.

A. *Parties.*—Parties will consist of two men each. The men should alternate in the use of the instruments and in tallying results.

B. *Equipment Required per Party.*

1 pair tree calipers.
1 Biltmore stick.
1 diameter tape.
1 dendrometer.
1 field note book supplied with Form 1.

C. *Method of Procedure.*

1. Obtain the diameters at breast height (D.B.H., 4.5 feet above ground) in inches and tenths, of at least 20 trees with each of the above instruments after first estimating the diameter by eye. The average diameter should always be taken . This can best be obtained by taking two measurements at right angles to each other.

In using the instruments note the following:

The Calipers.—See that the calipers are in adjustment. If they are, the closed arms will just fit together nicely when the handles of the arms are pressed together. It they are out of adjustment, adjust by means of the set screw on the movable arm. In using the calipers *be sure that the movable arm is pressed back against the scale-beam, and that the scale-beam is placed against the tree.* This will lessen inaccuracies due to the arm being out of adjustment. In calipering a large number of trees care is also necessary that the measurements be taken at a point 4.5 feet (D.B.H.) above ground.

The Biltmore Stick is based upon similar triangles, and assumes that the trees are perfectly round in circumference. To measure a diameter with this instrument place the stick flat against the tree at the point where the diameter is to be measured, being careful that it is held horizontal and perpendicular to the line of sight from the eye to the center of the tree. The eye should be arm's length, 25 inches, from the stick. Move the stick to right or left until the line of sight from the eye to the edge of the tree passes over the zero end of the stick. The diameter is then read where the line of sight to the opposite side of the tree strikes the stick. In making the reading be careful that the head is not moved and that the stick is not placed on a ridge or in a depression of the bark.

The Diameter Tape.—No especial directions concerning the use of the diameter tape should be necessary. If a diameter tape is not available use an ordinary tape graduated into feet and tenths and divide by π. Reduce to inches by multiplying by 12.

The Dendrometer.—Since the types of dendrometers available are so varied special directions for using will have to be given by the instructor. In this connection the author has devised and extensively used an instrument termed a "tree cross" which is based upon the principle of the Biltmore stick except that the scale is attached by means of a sliding and swiveling joint fifteen inches from the end of a staff which is sixty inches long. The measurement is taken by placing the end of the staff nearest the scale against the cheek, the other end against the tree pointing towards the center and reading the scale as is done with the Biltmore stick.

Tally the measurements of each tree according to the following form of notes:

Tree No.	Ocular estimate	Diameter tape	Biltmore stick	Dendrometer	Tree calipers

When all measurements have been taken on the 20 trees, add up the total inches in each column; find the difference between each one of these totals and the total value secured with the calipers.

Using the calipers as a standard now find the percentage of error by dividing the difference obtained by the total number of calipered inches.

Comment on the comparative efficiency of the various methods and instruments as to accuracy, portability, etc.

3. In order to develop proficiency in estimating diameters by eye now make an ocular estimate of a large number of trees, checking each estimate with the calipers.

D. *References.* Numbers 1, 2, 3, 5, 6, and 10.

NOTE.—All numbers to references in this and succeeding problems refer to Bibliography in the Appendix.

PROBLEM 3. (Field.) THE DETERMINATION OF THE HEIGHTS OF STANDING TREES.

EXPLANATION.—The object of this problem is to give practice in estimating the heights of standing trees by eye and other rough methods, and by means of hypsometers, and to compare the efficiency of the various methods.

DIRECTIONS.

A. *Parties.*—Students will work in two-man parties, alternating in the use of instruments and in tallying results.

B. *Equipment Required.*—All the different types of hypsometers available, a 100-foot tape, and notebook supplied with Form 1.

C. *Method of Procedure.*

1. Select a tree standing in the open and measure its height accurately by means of a transit or other accurate method designated by the instructor. In using the transit, set up at any convenient horizontal distance measured from the tree, and read the vertical angle to the top of the tree. With a table of natural tangents of a right angle triangle compute the height of the tree above the level of the center of instrument. In a similar manner obtain the height below this level and add the two for the total height of the tree.

2. Measure this tree by the following rough methods: (*a*) shadow, (*b*) two-pole, (*c*) prostrate, and (*d*) with single pole, and with as many of the following hypsometers as are available: (*e*) Klaussner, (*f*) Faustman, (*g*) Weise, (*h*) Winkler, (*i*) Christen, (*j*) Brandis, (*k*) Goulier, (*l*) omnimeter, (*m*) Abney level, (*n*) Barbow compass, (*o*) Forest Service Standard, (*p*) Forest Service Compass. (See note for description of rough methods.)

NOTE.—The various rough methods are described below:

Shadow Method

(a) Stick a pole of any convenient length, upright in the ground and measure its height above the ground.
(b) Measure the shadow of the pole and the shadow of the tree and by proportion compute the height of the tree.

Two-Pole Method

(a) Stick a pole about 4 feet long, upright in the ground at any convenient distance from the tree.
(b) About 6 feet away from this pole and in line with the first pole and the tree place a second pole about 10 feet high.
(c) Sight from top of the short pole and make marks on the long pole at the intersections of the lines of sight to the top and to the base of the tree.
(d) Measure the length between these marks, the distance from the top of the short pole to the base of the tree and the distance from the top of the short pole to the lower mark on the long pole.
(e) By proportion compute the height of the tree.

Prostrate Method.

This method is similar to the two-pole method, except that the short pole is dispensed with and the observer takes the sight by lying on his back on the ground with his foot against the long pole.

Single-Pole Method

(a) Hold a pole about 5 feet long at arm's length loosely between the fingers of one hand, so that it will swing into an upright position and so that the portion of the pole above the hand is equal in length to the distance of the hand from the eye.
(b) Without changing the position of the hand with reference to the eye, step slowly forward or backward until the line of sight to the base of the tree strikes across the hand, and the line of sight to the top of the tree just includes the tip of the pole.
(c) The height of the tree then equals the distance of the observer from the tree.

3. After using the rough methods, use the different hypsometers.

4. Tally all measurements, on Form 1, according to the following form of notes:

Instrument or method	Total Height	Error from Standard +	Error from Standard −	Remarks
Two pole....	83		1	
Faustman...	84	0	0	

The third column will be used for entering the error of each instrument or method from the height as measured by the transit or other accurate method. The "Remarks" column will be used for entering the estimator's reasons for condemning or recommending the instrument or method.

5. In order to develop proficiency in securing heights by eye now estimate the heights of a large number of trees by eye. Check each estimate with the hypsometer found to be the best.

D. *References.*—Numbers 4, 8, 10, 11 and 12.

PROBLEM 4. (Office) THE CONSTRUCTION OF A DENDROMETER.

EXPLANATION.—The object of this problem is to illustrate the principles underlying the construction of dendrometers such as the Biltmore stick or other similar diameter measures, and to construct an instrument which can be used in later field problems.

The formula for securing the length of graduation of the Biltmore stick is:

$$x=\frac{25D}{\sqrt{25^2+25D}}$$

where x = the length of graduation;
D = the diameter of the tree;
25 = distance in inches from the eye of the observer to the circumference of the tree.

DIRECTIONS.

A. *Method of Procedure.*

1. Draw a diagram illustrating the principle of the Biltmore stick described in Problem 2.
2. Work out the complete algebraic proof of the formula given above for securing the length of graduation of the stick in terms of the 25-inch distance and the diameter of the tree.
3. Compute the exact length of graduation for each two-inch diameter class for trees from ten to sixty inches.
4. Select a hardwood stick approximately $\frac{3}{4}$ inch square and of a suitable length, and bevel off one side. Upon this side mark the graduations just computed.

B. *References.*—Numbers 1, 2 and 3.

C. *Discussion.*

1. In what respects would the proof of the principle of the tree cross mentioned in Problem 2 be different from that for the Biltmore stick?
2. Give a list of the advantages and disadvantages of the tree cross as compared with the Biltmore stick.

PROBLEM 5. (Office) THE CONSTRUCTION OF A HYPSOMETER.

EXPLANATION.—The object of this problem is to illustrate the principles underlying the construction of a hypsometer such as the Christen or the

Merritt (Biltmore Stick) and to construct an instrument which can be used in later field problems. Either of the illustrations may be used.

ILLUSTRATION 1.—Construction of the Christen Hypsometer.

EXPLANATION.—The Christen hypsometer consists of a flat piece of brass or wood with a notch near each end between which are placed graduations representing heights of trees. The lengths of these graduations are secured by the following formula:

$$x = \frac{A \times B}{C}$$

where x = length of graduation, measured upward from the lower notch, inches;
A = distance between notches, inches;
B = length of the pole, feet;
C = height of the tree, feet.

In using the instrument the observer holds the upper end of the instrument suspended between his fingers, in front of his eyes and at any convenient distance away. An assistant holds upright against the base of the tree a pole of the certain length upon which the graduations of the instrument are based. The observer obtains the height of the tree by moving towards or from the tree until it is just included between the notches and then reads as the height of the tree the graduation intersected by the line of sight to the top of the pole.

DIRECTIONS.

A. *Method of Procedure.*

1. Draw a diagram illustrating the principle upon which the instrument is based and write out the complete algebraic proof.
2. For finding the length of graduations of the instrument in terms of the distance between the notches of the instrument, the height of the tree, and the length of the pole used with the instrument, proceed as follows:
   (*a*) Using 10 feet as the length of the pole and 12 inches as the distance between the notches of the instrument, work out the length of the graduation measured upward from the bottom notch for each five feet of height for trees from 20 to 100 feet in height.
   (*b*) Shape a stick $13 \times 1 \times 0.25$ inches with notches 12 inches apart and to a thin beveled edge between the notches, and mark the computed lengths of graduations on the beveled edge of the stick.

ILLUSTRATION 2.*—Construction of the Merritt Hypsometer.

EXPLANATION.—Markings may be placed upon the reverse side of the Biltmore stick. It should be held upright in the hand 25 inches from the eye of an observer when stationed $1\frac{1}{2}$ chains from the tree.

*Note—A third type of hypsometer easily may be made by attaching near one corner of a board $\frac{1}{2}$x$3\frac{1}{2}$x8 inches, a piece of wire which may swing as a pendulum. Graduations for tree heights may then be computed and marked along the opposite long edge of the board.

A. *Method of Procedure.*

1. In a manner similar to that explained above draw a diagram illustrating the principle and work out the formula for deriving the length of graduations of the Biltmore stick when used for securing the 16.2-foot log lengths in standing trees.
2. Compute the length of graduation measured upward from the zero end of the Biltmore stick for each 16.2-foot log from one to eight.
3. Mark these graduations on the reverse side of the Biltmore stick constructed in Problem 4.

PROBLEM 6. (Field) THE COLLECTION OF DATA FOR VOLUME STUDIES.

EXPLANATION.—The object of this problem is to illustrate practically the methods of taking measurements necessary for volume studies of every character. The student should realize at the outset that certain special studies require only certain of the measurements here called for and that when such special studies are to be made the first step in the work should be to determine just what measurements are necessary, so that all unnecessary measurements may be eliminated.

The organization of parties and the routine as here suggested have been found efficient in Pacific Coast timber, though it may not prove so for the timber of other regions without slight modifications. Likewise, when a smaller variety of measurements is required, some changes in this routine may be necessary. The proper key to the situation has been found only when each member of the party is kept busy without any "waits," for if any man has to wait on any of the others, the party is not efficiently organized. The lengths in which the sections will be measured and the top diameter limit to which D.O.B. (diameter outside bark) will be taken will ordinarily depend upon the use which is to be made of the data. If they are to be used for the construction of a rough "Used Volume Table" showing the average contents of trees as utilized at a specific logging operation, measurements will be taken to the last saw cut, and the length of sections will correspond with the log lengths cut by the logger.

If on the other hand the data are to be used in the construction of a general volume table, a practically uniform volume should be secured for all trees of the same size and shape. To do this the sections must be taken in regular lengths up to a certain fixed diameter in the top, independent of the variable lengths into which different trees are cut by the logger. In such cases a certain length, such as 10.2 feet, 16.2 feet, or other regular length with a slight overlength above the even foot to allow for trimming in the mill, is determined upon in advance of the work, and trees are all measured in this length of section up to a certain fixed limit in the top, as for example 6, 8 or 10 inches.

The tree will then be divided into sections of this length up to the fixed top diameter limit, regardless of whether the bole is broken or defective or of how the tree has been cut into logs by the logger. In case the bole of the

tree from the stump-cut (or from a fixed height above the ground should the measurement of the log sections not be started from the stump) up to the top diameter limit does not contain an even number of regular sections, the last section and the fractional section will be broken into two even-foot lengths of as nearly equal length as possible. Example: In measuring to an 8-inch top diameter limit with 16.2-foot sections, suppose there results a section at the top 10.2 feet long. Instead of taking the last two sections in these lengths, they should be broken into a 14.2-foot length and a 12.2-foot length with the short length at the top and the D.O.B. measurements taken at the top ends of these sections.

Care must be used in selecting the trees for measurement in order that a range of sizes may be obtained and in order that only normal specimens are included. Abnormal trees or trees with any kind of malformation should not be measured. However, trees which are broken or are defective, as long as the defect does not affect their shape, may be taken, but they should be measured as entirely sound with no attention given to the defect.

Illustration.—To Collect Data for a General Full Stem Volume Study.

Directions:

A. *Parties.*—The following organization of the men into 3-men parties, with the duties of each as indicated, will be found efficient: 1. The Notekeeper, who is chief of party, is responsible for all work, and tallies all measurements called out to him. 2. The Caliperman measures the D.B.H. and all other diameters outside of bark with the calipers, and the average width of bark with the analysis rule. 3. The Poleman locates the D.B.H. and measures the length of all sections including the stump and tip, and the clear length.

B. *Equipment Required for Each Party.*

1 pair tree calipers.

1 six-inch flat boxwood or metal rule graduated into inches and tenths.

1 8-foot pole, graduated into feet and tenths, and with the D.B.H. point (4.5 feet) plainly indicated.

1 piece carpenter's crayon.

1 belt axe.

1 field notebook supplied with Form 2A.

C. *Summary of Measurements Required.*

Measurements	Unit	Instrument
1. Stump height	Foot to nearest 0.1 ft.	8-foot pole
2. Stump diam. outside bark (D.O.B.)	Inch to nearest 0.1 in.	Tree calipers
3. Width of bark on stump	Inch to nearest 0.1 in.	Boxwood rule
4. D.B.H. outside bark	Inch to nearest 0.1 in.	Calipers
5. Length each section and tip	Foot to nearest 0.1 ft.	8-foot pole
6. D.O.B. end of each section	Inch to nearest 0.1 in.	Calipers
7. Width bark end each section	Inch to nearest 0.1 in.	Boxwood rule
8. D.I.B. end of each section	Inch to nearest 0.1 in.	(Calculated by notekeeper)
9. D.O.B. at middle of total height	Inch to nearest 0.1 in.	Calipers

D. *Method of Procedure.*

1. The chief of party should systematize the work as soon as possible, for not until each man knows exactly what to do, and follows the same routine for each tree, will the work progress rapidly and efficiently.
2. The following method of procedure has been found efficient in Pacific Coast timber:

The Poleman.

(*a*) The poleman first approaches the stump of a tree, marks it with the crayon to prevent repetition, and then, setting the 8-foot pole alongside it, obtains its height. Care must be used not to measure the longest nor the shortest height, but the average. The poleman then calls out the measurement to the notekeeper and before proceeding further waits for him to repeat the figure to avoid errors in tallying.

(*b*) Keeping his thumb on the pole at the point which indicates the height of the stump, he lays the pole along the first log with his thumb against the saw cut. The breast high point on the pole now shows where the D.B.H. measurement should be taken. This point is kept until the caliperman takes the D.B.H. or it is indicated by an axe or crayon mark.

(*c*) Starting from the saw-cut at the butt of the first log the poleman now proceeds along the bole (up the tree) measuring the lengths of all sections, including the tip, and the clear length, in feet and tenths. The length of the tip should be carefully measured to the terminal bud, and if broken, a little time and care should be used to find the missing pieces. If they cannot be found, however, the length actually found should be measured and recorded as "found top"; and the missing part should then be estimated, and recorded as "estimated top" on the tally sheet (analysis sheet.) The clear length, which is the length from the large end of the butt log to the first prominent green limb, should be measured as the poleman proceeds up the bole.

The Caliperman.

(*a*) The caliperman follows close behind the poleman, measures and calls out to the notekeeper the various diameters and thickness of bark measurements as they are obtained in order. First, he obtains the D.B.H. at the point indicated by the poleman. This, since it is the most important of all measurements, should be obtained with great care by taking the longest and shortest diameters, or, when this is obviously impractical, by two measurements at right angles.

(*b*) Next, he measures the D.O.B. at the stump, again taking an average of the longest and shortest diameters, and the average width of bark determined by two or more measurements. Every time he calls out a measurement he should wait for the notekeeper to repeat it.

(*c*) In a similar manner he proceeds along the bole and obtains the D.O.B., and width of bark at the top end of each section. Should the sections not be measured in the same lengths as cut by the logger, the width of bark will have to be secured by chopping through it, taking care to have the cut surface perpendicular at the point where the D.O.B. is secured. Often when the saw cut is not over a few feet from the point where the measurement is to be taken, or in rough work, the width of the bark of the nearest saw cut may be entered as that of the section being measured. A few trials will readily show to what extent this is permissible.

(*d*) The D.O.B. at the middle of the total height of the tree will be measured in order to compare the two methods of computing volumes of trees explained in Problem 13. It is not required in ordinary work.

The Notekeeper.

(*a*) The notekeeper should always repeat the values as they are called out to him as a check in tallying the measurements.

(*b*) Before leaving a tree he should check over his tally sheets to ascertain whether any necessary measurements have been omitted. At odd moments he should also make the following calculations and record them in the proper spaces on the tally sheet.

1. Diameter inside bark at each section, obtained by doubling the width of bark and subtracting from the D.O.B.
2. The total height, obtained by adding together the length of all sections, including stump and tip.
3. The used length, which represents the sum of the log sections just as used by the logger, and hence does not include stump and tip.
4. The merchantable length. This may be the same as the used length though not necessarily. It is usually not when it is determined between a fixed diameter limit in the top, irrespective of the sections as cut by the logger.

E. *Discussion.*

1. Supposing that the field data were to be obtained for the construction of a volume table on the D.B.H. only, and intended to show the contents of trees as cut by the logger, how would the above method of

procedure be varied as to the list of the measurements taken, the organization of the work, and the accuracy required?

2. How would you proceed if you were to collect data in a tie operation for the construction of a tie table?
3. Give the method of procedure, measurements necessary, etc., for collecting data for a cordwood table.
4. In the collection of volume table data, why are broken or defective sections of a tree scaled as if sound?
5. Why are the measurements for a general table usually taken in regular length sections (*i.e.* 16.2), rather than in the same lengths as cut by the logger?
6. Explain the difference between *fixed*, *merchantable*, and *used* limits for the top diameters of trees measured.
7. How would the organization of the work in a full stem volume study be changed if there were only two men in the party?
8. What is the object of taking the clear length, and when should it be omitted?

PROBLEM 7. (Field) THE COLLECTION OF DATA FOR GROWTH STUDIES.

EXPLANATION.—The illustration given below aims to include all measurements required in any growth study concerning itself with the stem of the tree (hence it does not include branches), and unless a specific problem involves a *full stem analysis* all of the measurements enumerated below may not be required. As in Problem 6, the student should realize that the first important step in the collection of data for any specific problem will be to determine just what measurements are required.

ILLUSTRATION.—To make a Complete Stem Analysis.

DIRECTIONS.

A. *Parties.*—The organization of men into parties will be the same as for Problem 6, except that the taking of the D.B.H. and the D.I.B. measurements of each section will be added to the duties of the pole-man; and the caliperman now becomes the ring counter. The duties of the latter will be to count the rings at each cut, to make the decade measurements, and to obtain the thickness of bark.

B. *Equipment Required for Each Party.*—Same as for Problem 6, with the addition of a small hand magnifying glass to aid in counting the annual rings and an analysis or similar rule graduated into inches and twentieths. If the trees are more than 21 inches in diameter inside the bark at the stump, the analysis rule should be 24 inches long. It will also be found a great aid to the work if this is supplied with a centering point attached at the zero mark.

C. *Measurements Required.*—The measurements will correspond to those outlined for Problem 6, except that the D.I.B. at the top end of each section will be taken instead of the D.O.B. The following additional measurements will also be necessary:

Measurements	Unit	Instrument
Total age	Years	To be determined by a separate special study on seedlings; see Problem 25
Age at each cross-cut	Years	Hand lens
Measurements taken on average radius in ten-year periods (decades)	Inches to nearest 0.05	Analysis rule

D. *Method of Procedure.*

1. *The Poleman.*

The Poleman, with the added duties of caliperman, will follow the same routine as before (see Problem 6), except that both series of measurements will be made at the same time as he proceeds along the tree.

2. *The Ring Counter.*

(*a*) The Ring Counter first obtains the average width of the bark.

(*b*) Then with the D.I.B. as obtained by the poleman he computes the average radius, and with the centering pin at the pith of the tree he swings the analysis rule until the length of the average radius just cuts the outer edge of the last ring.

(*c*) A straight line is now drawn from the pith to the bark along this radius. The rings are then counted from the bark to the pith and the tenth ring of each decade marked with a soft pencil. Care should be used to place the mark *within* the *tenth* ring.

(*d*) The total age at the cut and the distances from the pith to each tenth ring are then read off to the note-keeper in inches to the nearest 0.05. In reading off the decade measurements care should be taken to read to the inner edge of the early wood of each of the marked rings.

3. *The Tallyman.*

(*a*) The Tallyman records the measurements in the proper column on the Tree Analysis Blank (Form 2A and B.) In recording the first decade measurement it will be found that it usually does not represent a full period of ten years. The number of rings included in this measurement should therefore be indicated in the upper left-hand corner of the space allotted to this measurement on the back side of the sheet (Form 2B.), and divided off from this space by a diagonal line.

(*b*) He should make the following checks on the analysis sheet.

1. The last decade measurement should equal one-half the D.I.B. as previously tallied.
2. The age at any cut should be equal to the total number of decades minus one, times 10, plus the number of rings recorded in the upper left-hand corner of the space allotted to the first decade measurement.
3. The consecutive cross-sections should show a decrease in age from stump to tip.
4. Before leaving the tree he should carefully check over the entire tally sheet to see that none of the necessary measurements have been omitted.

(*c*) In making the necessary calculations he determines the D.O.B. at each cut instead of the D.I.B. as was done in Problem 6. This is done by adding twice the thickness of the bark to the recorded D.I.B.

E. *References.*—Numbers 7, 9 and 80.

SECTION II—USE OF GRAPHIC METHODS

PROBLEM 8. (Office.) THE FUNDAMENTAL PRINCIPLES IN THE USE OF GRAPHIC METHODS.

EXPLANATION.—In this problem one of the simplest problems involving the plotting of curves has been chosen and outlined primarily with reference to illustrating the fundamental principles of determining averages by means of plotted values, and to show something of the significance of bringing out a series of related results by graphic representation.

ILLUSTRATION.—To Make a Table of Average Heights on Diameters by Plotting the Values on Co-ordinate Paper.

DIRECTIONS:

A. *Data Required.*—Measurements showing the total heights of trees of different diameters at breast height. Use Data Series I in the Appendix.

B. *Method of Procedure.*

(*a*) *Preparing the Co-ordinate Paper.*

1. The problem used to illustrate this exercise aims to determine an average height for certain specified diameters, *i.e.*, the diameters of the trees are independent variable quantities and the heights dependent variables. As it is customary to let abscissæ on the cross-section paper represent the independent values and ordinates the dependent values, in this problem let the abscissæ represent diameters and the ordinates heights. It is a rule to let horizontal distances from the vertical axis represent abscissæ, and vertical distances from the longitudinal axis ordinates.
2. Having determined which values shall be represented by abscissæ and which by ordinates, the next step is to determine the limits of variation which the data will represent (*i.e.*, in this problem, what are the smallest and the largest values for diameters and for heights that it will be necessary to plot?), so that the unit best adapted for each of the co-ordinate axes can be decided upon. In deciding this unit, remember that the larger the unit the more accurate will be the results (so that the entire sheet of paper should be utilized as far as practicable), and also that

the general aim should be to *choose such units that the curve will be neither very flat nor very steep. This aim is accomplished if the largest ordinate is not more than one and one-half times the largest abscissa. Remember this in connection with all curves.*

3. Having determined the units for ordinates and abscissæ, starting from the lower left-hand corner of the page lay off and mark the respective values on each axis. Always *label* these carefully along the edge of the paper; *i.e.*, "Diameters in Inches," "Heights in Feet," etc.
4. In plotting the values remember, as before stated, that the horizontal distances from the vertical axis represent the values of the abscissæ (diameter values in this case), and that the vertical distances from the horizontal axis represent the ordinates (heights in this case.)

   The two variable quantities, the height for a specified diameter, can be expressed by a single point on the co-ordinate paper; namely, that point at which the perpendicular lines extending from the respective abscissa and ordinate axes cross. After the location of the first point has been determined plot the values of all other trees in the data supplied. Where a second point occurs at the intersection of the same lines place a small figure "2" beside the point already plotted, for a third point of the same value a small figure "3," and so on.

(*b*) *Averaging the Values.*

5. When plotting is completed, the next step is to average the values in accordance with the object sought. In this problem the average height will be determined for each 2-inch diameter class in even inches. Remember that in all of these problems two sets of averages must be obtained. In this problem we have (1) the average heights for the diameter classes and (2) the average diameter of each diameter class. Let each of the diameter classes begin with the fractional part of the preceding whole odd inch and end with the next succeeding whole odd inch, of the diameter class, *i.e.*, 5.1 inches to 7.0 inches inclusive will comprise the 6-inch class. In 1-inch classes it should be from 5.6 inches to 6.5 inches inclusive. The average abscissa for each diameter class will be found by adding horizontally the values of all points plotted within each diameter class, and dividing by the total number of points. Similarly the average ordinate for each diameter class will be found by adding vertically the values of the same points, and dividing by the number of points. With these two average values at hand now plot the average point in its proper place as was done with the points for the individual trees. *In order that this point may be distinguished from the others*

enclose it within a small circle or square. Opposite the average point enter the number of trees that the point represents.

Note.—The following short cut in averaging saves a great deal of time. Instead of adding the actual values represented by the plotted points, let the first heavy line below and a similar one to the left of the group of points to be averaged represent zero lines. Now find the value of each point in terms of the number of spaces it is located from the new zero. Average, and locate the new point accordingly.

(*c*) *Drawing the Curve.*

6. Connect the average points by fine straight lines. This will help to show the general direction of the curve.
7. Next locate the direction of the curve by eye. In doing this imagine the curve as a flexible steel band so placed that the average points, which are considered as magnets of a strength dependent on the number of trees represented, are about equally located on either side of it. The band will then take a position nearest the points with the greatest attractive force. After locating the direction of the curve by the eye, sketch in it free-handed as smoothly and regularly as possible, and finally smooth off the irregularities by means of a spline or adjustable curve.
8. From this curve construct a table of heights for each diameter in whole inches by noting the points where the respective perpendicular lines from the co-ordinate axes meet the curve.

C. *Discussion.*

1. Supposing that the method of first averaging and then plotting the averaged points were used instead of that described above, explain in detail how the method of procedure would be varied.
2. Why can not the data be averaged in the above problem just as well without plotting values and drawing a curve?

SECTION III—LOG RULES

PROBLEM 9. (Office.) The Construction of a Scientific Log Rule.

Explanation.—The object of this problem is to illustrate the fundamental principles underlying the determination of the contents of logs in board measure. A thorough preliminary study of a rule such as the International, which is constructed upon scientific principles, should give the student a thorough understanding of the determination of the contents of logs in board feet, and a scientific foundation upon which to base his general study of log rules.

Illustration.—The International Log Rule.

The formula for securing the volume of a log 4 feet in length by the International log rule is

$$V = 0.22D^2 - 0.71D,$$

where V = the volume of the log in feet B.M.;
D = the diameter in inches at the top end of the log.

This formula is based upon the assumption of a loss for each 1 inch board of $\frac{1}{8}$-inch in saw kerf, and $\frac{1}{16}$ inch for shrinkage and that the loss in slabbing, edging and surface waste is equivalent to a board 2.12 inches thick, of the same width as the diameter of the log and the same length as the length of the log.

Directions:

A. *Methods of Procedure.*

1. Work out the complete algebraic proof of the International rule for 4-foot lengths, noting the reason for each step.
2. Using the formula for 4-foot lengths, and allowing $\frac{1}{2}$-inch taper for each 4 feet, compute the volumes of the logs of all diameters from 6 inches to 16 inches inclusive, and each length in even 4-foot lengths from 8 feet to 24 feet (*i.e.*, 8-, 12-, 16-, 20- and 24-foot lengths). Arrange the results in table form leaving blank spaces for the alternating even-foot lengths (*i.e.*, 10-, 14-, 18-, and 22-foot lengths.)
3. Now determine the values for the missing alternating lengths by plotting a separate curve for each diameter from 6 inches to 12 inches using abscissæ as lengths, and ordinates as volumes.

4. From these curves read off the volumes for the missing lengths, and enter in the table.
5. Take a smooth stick $0.5 \times 1 \times 13$ inches and enter on it the values in the table in the same manner as they occur on the ordinary scale stick.

B. *References.* Numbers 17, 18, 25, 26, and 27.

C. *Discussion.*

1. Write brief directions for using the scale stick in scaling logs.
2. What is the object in drawing the curve in this problem?
3. What particular fundamental principles make the International Rule more accurate than other formula rules such as the Doyle.
4. What advantages has a formula rule over a diagram rule?

PROBLEM 10. (Office.) The Graphic Comparison of Log Rules.

Explanation.—To illustrate the extreme variations in values obtained by scaling with different log rules.

Illustration.—The International, Scribner, and Doyle Rules.

Directions:

A. *Method of Procedure.*

1. On a sheet of co-ordinate paper lay off diameters in inches as abscissa on the long edge of the sheet, and volumes in board feet as ordinates. Be sure first to determine the number of spaces you will allow to each unit by an examination of the data to be plotted.
2. With values read from a scale stick, or from the respective tables in Graves' *Mensuration* or the Woodsman's Handbook, Bull. 36 U. S. Dept. of Agr., construct on the same sheet of cross-section paper curves representing the values of the 16-foot logs of all diameters given by the International, the Scribner, and the Doyle Rules.

B. *References.* Numbers 16, 19, 20, 23 and 24.

C. *Discussion.*

1. Comment on the relationships as illustrated by the curves.
2. Could a combination table for the "Doyle-Scribner" Rule be constructed so as to yield low values?

PROBLEM 11. (Office.) The Extension of Log Rules.

Explanation.—The object of this problem is to show how log rules with values reading only to a certain point may be extended so that the rule may be applied to logs of other dimensions. The method of procedure here outlined for log rules may also be used in the extension of volume, growth, or any other

tables in which the values vary more or less regularly according to some definite law.

ILLUSTRATION 1.—Extension by prolonging a curve.

EXPLANATION.—The Drew Rule has been chosen for this illustration because it gives values only for logs above 20 feet in length. The object will be to extend the values for 16-inch logs so that they may be scaled down to 10-foot lengths.

DIRECTIONS:

A. *Method of Procedure.*

1. With lengths in feet as abscissæ and volumes in board feet as ordinates, plot the following values for 16-inch logs by the Drew Rule.

Length, Feet	Volume, B.M.	Length, Feet	Volume, B.M.
20	194	32	311
22	214	34	330
24	233	36	350
26	252	38	369
28	272	40	388
30	291		

2. Extend the curve backward to 10 feet. Be careful that the extended portion of the curve follows the same general trend as the original curve.
3. Read values from the curve for lengths from 20 feet down to 10 feet in 2-foot classes and tabulate.
4. The values for other inch classes may be extended backward in a similar manner, and the values thus secured tabulated.

ILLUSTRATION 2.—Extension by interpolation.

EXPLANATION.—The Vermont Rule gives the following board foot contents for 16-foot logs.

Diameter, Inches	Volume, B.M.	Diameter, Inches	Volume, B.M.
6	24	16	170
8	43	18	217
10	66	20	267
12	96	22	320
14	130	24	384

The object will be to extend this rule so that volumes for logs up to 36 inches in diameter can be obtained.

DIRECTIONS:

A. *Method of Procedure.*

1. Find the difference in volume between the diameters of 14 and 16 inches, 16 and 18 inches, 18 and 20 inches, 20 and 22 inches, 22 and 24 inches.
2. Find the average of these differences.
3. Find the average increase of these differences.
4. To the value of a 24-inch log as given in the table add the average difference found in 2, plus the average increase found in 3 and the volume of a 26-inch log will be obtained.
5. Secure the volume of a 28-inch log similarly by adding to the value of a 26-inch log the average difference plus twice the average increase.
6. Continue this operation for all even diameters up to 36 inches and tabulate.
7. The values for other log lengths may be extended in a similar manner and the values thus secured tabulated.

B. *References.* Number 21.

C. *Discussion.*

1 From this problem and the preceding one would you say that there is ever any justification for extending a log rule by tacking one rule onto another?

2. What are the different uses of plotted curves as illustrated in Problems 8, 9, 10 and 11.

SECTION IV—PRELIMINARY CALCULATIONS

Explanation.—The object of this section is to give the student sufficient practice in making calculations by means of the various units used in forest mensuration, so that such calculations may be largely dispensed with in succeeding problems wherein they become merely clerical work.

PROBLEM 12. (Office.) The Determination of the *Merchantable* Contents in *Board Feet* of Felled Trees.

Directions:

A. *Data Required.*—Use the tree measurement data collected in Problem 6.

B. *Method of Procedure.*

1. With the aid of a Scribner decimal C log table or scale stick determine the volume in board feet of each log section measured except stump and tip, as shown by the length of the section (log) and the diameter inside of bark at the small end of the section. Round off all diameters to the nearest whole inch above or below the actual diameter. In rounding off diameters classify logs with diameters exactly half-way between inches (0.5 inch) in the next lower inch. Place all lengths in the even 2-foot length next below the actual size, unless "penalty scaling" is practised in which case place logs which exceed a certain amount allowed for trimming in the sawmill, in the next higher even-foot length. Enter the volumes in the proper columns on the analysis blank. (Form 2A.) Since in the construction of the Scribner decimal C rule the end figure is *dropped*, add a cipher to the volume of each section as read from the table to secure the full scale of the log to the nearest 10 feet.

Note.—Where the Scribner decimal C. rule is used for scaling Pacific Coast timber, the maximum scaling length of any section should not exceed 32 feet; *i.e.*, logs up to and including 32 feet in length should be scaled as one log, and logs longer than this as two logs of as nearly equal even-foot lengths as possible, the shorter length to be taken nearer the smaller diameter. In this case the diameter at the end of the larger log will be determined in Pacific Coast species by allowing one inch increase for every 10 feet of length for taper; *i.e.*, for lengths from 5 to 15 feet allow 1 inch, for lengths from 16 to 25 feet 2 inches. To illustrate further, a 36-foot log should be broken into two 18-foot sections, and the diameter at the end of the butt section as 2 inches larger than the top diameter at the small end of the whole (36-foot) log. Similarly, a 38-foot log would be broken into a 20-foot section and an 18-foot section, the longer section at the butt end with a diameter 2 inches larger than the top section.

2. Add the volumes of all sections to determine the total merchantable volume of the entire tree, and record in proper space.

C. *References.* Number 45.

PROBLEM 13. (Office.) THE DETERMINATION OF THE *Total Cubic* CONTENTS OF FELLED TREES.

EXPLANATION.—The object of this problem is to show the comparative value of the different methods and to develop proficiency in making the various fundamental calculations required in the determination of the cubic contents of trees.

ILLUSTRATION I.—To compute the cubic contents of felled trees by cubing the tree in sections.

EXPLANATION.—In this method each section in the tree is compared to a geometric figure and for that reason logs, stumps, tips and branches each require the use of a distinct formula. The various formulæ follow:

A. *The Cubic Contents of Logs.*

1. Let B = basal area in square feet of large end of log;
   b = basal area in square feet of small end of log;
   L = length of log.

   Then the cubic contents may be expressed by Smalian's formula as follows:

$$\frac{B+b}{2}\times L.$$

2. Determine basal areas in square feet by,—

$$\frac{\pi d^2}{4}\times\frac{1}{144},$$

   Where d = the diameter of the area in inches and $\frac{1}{144}$ is used to reduce to square feet.

B. *The Cubic Contents of Stumps.*

A stump is treated as a cylinder whose diameter is equal to the top diameter of the stump. The formula for the cylinder is

$$B\times L.$$

C. *The Cubic Contents of Tips.*

A tip is treated as a cone whose basal area is equal to the basal area of the tip, and whose altitude is equal to the length of the tip. The formula is,

$$\tfrac{1}{3}B\times L.$$

D. *The Cubic Contents of Branches.*

A branch is treated as a cylinder whose diameter is equal to the diameter of the middle of the branch. Letting $B_{\frac{1}{2}}$ equal the middle diameter and L the length, the formula becomes,

$$B_{\frac{1}{2}} \times L.$$

DIRECTIONS.

A. *Data Required.*—Use the data collected in Problem 6.

B. *Method of Procedure.*

1. Compute the contents of one tree according to the formulæ given in the Explanation.
2. In the remaining data use, in place of the formula for basal areas, the table of basal areas given in the Appendix (Table III.).
3. Tally all volumes in the proper column on the analysis blank and total.

ILLUSTRATION 2.—To Compute the Cubic Contents of Felled Trees by Cubing the Tree as a Whole (Schiffel Method).

EXPLANATION.—The following formula for securing the full stem volumes of trees, devised by Professor Schiffel of the Austrian Experiment Station, has recently been introduced in this country.

$$\text{Cubic contents of a tree} = (0.16\ B + 0.66b)H,$$

where B = area in square feet at the D.B.H. point;
b = basal area in square feet at the middle of the total height;
H = total height in feet.

This formula is explained in the "Centralblatt für das gesamte Forstwesen" for December, 1906. It has not yet gained general use in the United States as its accuracy has not been completely established. This illustration serves to compare its accuracy with the Smalian method of cubing trees.

DIRECTIONS.

A. *Data Required.*—Use the same data as in Illustration 1.

B. *Method of Procedure.*

1. Compute the cubic volume of one tree using the Schiffel formula.
2. In the remaining data use tables Number I and II in the Appendix for finding value of 0.16 B and 0.66 b.

C. *References.*—Numbers 28, 29 and 31.

D. *Discussion.*

1. Comment on the relative accuracy of this method as compared with that of cubing each section separately outlined in Illustration 1.

2. In what way will this method decrease the necessary field work involved in securing the tree measurements?

PROBLEM 14. (Office.) THE DETERMINATION OF THE *Merchantable* CONTENTS OF TREES IN *Standards*.

EXPLANATION.—A *Standard* is a log of specified dimensions used as a unit of volume. It is based on the principle that the contents of logs vary directly as their *lengths* and the *squares* of their respective *diameters*. The volume of any log in terms of a specified standard may be obtained as follows:

"Square the diameter at the small end, and divide by the square of the diameter of the standard log; then divide by the length of the standard log and multiply by the length of the log measured."

ILLUSTRATION.—To compute the Merchantable Contents of Trees in the "19-inch Standard."

EXPLANATION.—The "19-inch Standard" is a log 13 feet long and 19 inches in diameter at the small end. The formula for determining the contents of a given log by this rule is,

$$V=\frac{D^2}{19^2}\times\frac{L}{13},$$

where V = volume in standards;
D = diameter inside of bark in inches at the small end of the log to be measured;
L = length in feet of the log to be measured.

DIRECTIONS.

A. *Data Required.*—Use the data collected in Problem 6.

B. *Method of Procedure.*

1. Compute the volumes of all sections except stump and tip in 19-inch standards.
2. Enter the values in a blank column on the analysis sheet, label properly and total.

PROBLEM 15. (Field.) THE DETERMINATION OF THE CONTENTS OF STANDING TREES BY SHORT METHODS.

EXPLANATION.—It is often necessary to determine the contents of standing trees by some short rule of thumb when no volume table or other better means is available. The student will find it very convenient to have one or more of these short rules at his constant command. Each of these methods should be tried out on 12 trees, except method II of Illustration 1, which will be used in connection with Problem 23.

ILLUSTRATION 1.—To Compute Contents in Board Feet of Standing Trees by the Spaulding Rule.

Explanation.—The Spaulding Rule is well adapted for Pacific Coast timber. The original Spaulding Rule was based upon diagrams but the following rule of thumb gives approximately the same result.

$$\text{Vol} = (D^2 - 3D)\frac{L}{20}$$ plus 3 per cent to 6 per cent of the value obtained by this formula.

where $D = \dfrac{\text{D.B.H.} + \frac{1}{2}\text{D.B.H.}}{2}$ and in which the D.B.H. is the diameter breast high inside the bark, in inches.

L = length from top of stump to point at which diameter inside bark is equal to one-half the D.B.H. inside bark. In practice it makes little difference whether this length be estimated with the $\frac{1}{2}$ D.B.H. point taken as one-half the D.B.H. outside the bark or one-half the D.B.H. inside the bark as long as both measurements are taken either inside or outside the bark.

The first part of the fo mula, namely that without the addition of the 3 to 6 per cent will give th volume of the tree up to the $\frac{1}{2}$ D.B.H. point. The additional 3 to 6 per cent will give the value of the merchantable portion of the tree above the $\frac{1}{2}$ D.B.H. point. In the case of trees with very tapering tips above the $\frac{1}{2}$ D.B.H. point, the lower percentage, namely 3 per cent, should be used, while for trees without excessive taper above the $\frac{1}{2}$ D.B.H. point a higher percentage, up to 6 per cent should be used. To compute the volume by this formula two measurements of the tree are necessary, the D.B.H. and the length from stump to $\frac{1}{2}$ D.B.H., which will be obtained as outlined in the method of procedure.

Directions.

A. *Parties.*—Men will be organized in two-man parties, each man alternating as cruiser and tallyman.

B. *Equipment Required per Party.*

1 pair tree calipers.
1 hypsometer.
1 dendrometer (if available).
1 field note book supplied with Form 3 A.

C. *Method of Procedure.*

Method 1.—By tallying D.B.H. and merchantable length for each tree.

1. Caliper D.B.H. outside bark of the trees whose volumes are to be computed.
2. By estimate determine width of bark at breast height, and check thickness of bark occasionally by chipping through it.

3. Estimate, checking the estimate occasionally with hypsometer, the height from stump up to ½ D.B.H. outside bark.
4. Tally these three measurements on Form 3 A, using one vertical column for each species. On the left-hand side of the column, opposite the proper D.B.H. class, enter the width of bark and on the right-hand side the height up to ½ D.B.H. for each tree calipered.
5. From these field measurements compute the volume inside bark of each tree from the formula.

Method II.—By tallying the D.B.H. of each tree and securing heights from a height curve.

1. Caliper D.B.H. outside bark of the trees whose volumes are to be computed.

   Note.—When the D.B.H. of a tree falls at a point where the bole is swell-butted the measurement should be reduced so as to give the tree the average amount of taper which in the judgment of the cruiser the conditions will warrant, for otherwise the formula will give results too high.

2. Take measurements of D.B.H., width of bark, and merchantable length to ½ D.B.H. on at least 30 fallen trees of various sizes.
3. From these measurements construct a height curve showing merchantable heights for different diameters breast high outside bark.
4. Using an average width of bark for each D.B.H. and with heights obtained from the height curves, compute volumes inside bark with the Spaulding Log Rule, for trees 20, 30, 40, 50, 60, 70 inches D.B.H. outside bark.
5. Plot the volumes of the sizes thus computed, connect with a curve, and read off the volumes of the intermediate diameters breast high outside bark.
6. Tally the volumes thus obtained in tabular form, and use this table for computing the volumes of trees calipered.

Illustration 2.—To Compute the Contents of Standing Trees in Board Feet by the Doyle Rule.

Explanation.—The Doyle Rule is simpler than the one described above but is not accurate for Pacific Coast timber, since it will give high results, as is the case when this rule is used with large-sized logs in any region. The rule follows:

$$\text{Volume of tree} = \left(\frac{D-4}{4}\right)^2 \times L.$$

D = middle diameter inside bark obtained by averaging the diameters at the top and base of the merchantable length of the tree;
L = merchantable length.

Directions.

To apply the Doyle Rule follow Illustration I, Method I, described above, except that the middle diameter should be tallied instead of D.B.H.

Illustration 3.—To Compute Contents of Standing Trees in Cubic Feet or Cords.

Explanation.—The object of this illustration is to demonstrate a method of determining the volume of standing trees in cubic feet or in cords. The Schiffel formula (see Problem 13, Illustration 2) may be used for computing the volumes in cubic feet and the contents in cords may be determined by dividing the total cubic volume by 90. This converting factor of 90 is based upon the supposition that a cord of wood contains 70 per cent solid wood. This of course will vary with the method of piling, and the size and form of the pieces. Should the trees be crooked or knotty, and the wood be split in small pieces, or should wood be wasted in the stump or top a converting factor between 80 and 90 should be used; on the other hand, should the timber be very smooth, straight and be cut in very large pieces a factor between 90 and 100 should be used.

Directions.

A. *Parties.*—Use the same party organization as for Illustration 1.

B. *Equipment Required Per Party.*—Use the same equipment as for Illustration 1, except that Form 1 should be substituted for Form 3 A.

C. *Method of Procedure.*

1. Prepare Form 1 with the following column headings on a separate sheet for each species:

D.B.H.	Total Height	D.M.H.	Vol. Cu. Ft.	Vol. Cords

The D.M.H. column will be used for tallying the diameter at the middle of the total height. The D.M.H. and total height of each tree should be tallied opposite its D.B.H.

2. Caliper the D.B.H. outside the bark of each tree.
3. Estimate, checking occasionally with a hypsometer, the total height of each tree.
4. Estimate, checking with a dendrometer if available, the D.M.H. outside the bark of each tree.
5. With the Schiffel formula work up the cubic volume including the bark of all trees and total.
6. Divide the total volume of each species in cubic feet by 90 to reduce to cords.

D. *References.*—Numbers 51, 64, and 65.

SECTION V—THE CONSTRUCTION OF VOLUME TABLES

Explanation.—The problems in this section have been chosen with reference to illustrating a number of fundamental problems which may serve as a basis for all volume table studies. Each problem illustrates some one or more specific features. These are emphasized in each instance in the italicized portions of the titles.

The relation of the specific features to related problems are brought out by special questions.

Caution.—In the problems of this section the student should use special care to label all work completely. The co-ordinate axes should be labeled with the unit being used, as "Volume in cubic feet"; and each completed curve and table should contain all the information necessary to give it scientific accuracy. Substantial reductions in grade will be made for any work turned in that is not properly and completely labeled.

The following points should be considered in the title of a completed volume table, though not all need be included, because some one condition may be wholly obvious from some others already stated:

1. Kind of table.
2. Species.
3. Forest type.
4. Locality.
5. Number of trees upon which table is based.
6. Top diameter-limit used.
7. Date.

PROBLEM 16. (Office.) The Construction of a *Merchantable* Volume Table in *Board Feet* Based on *D.B.H. Only.*

Directions.

A. *Method.*—Averaging the values first and then plotting the averaged points.

B. *Data Required.*—The student should determine first just what field measurements are necessary for the construction of a volume table of this kind. (See Problem 6.) Before beginning the work he should ask the instructor whether his conclusions on the point are right. Use Data Series I or the data collected in Problem 6. In case the latter are used the field work of the entire class should be used by each student.

C. *Method of Procedure.*

A. *Tabulation*

1. Divide a piece of blank note paper into tabular form with the following headings.

One Inch D.B.H. Classes	Tallied Values			Averaged Values	
	Tallied D.B.H.	Volumes B.M.	No. of Trees	Average D.B.H.	Average Volumes
11″ Class 10.6 to 11.5″					
12″ Class 11.6″ to 12.5″					

The horizontal lines should be spaced far enough apart to allow the data for all trees included in any 1-inch diameter class to be listed between them in a vertical column.

Label the spaces successively with the diameter classes they are to represent.

2. Tally in a vertical column in the space allotted to the D.B.H. measurements the actual breast high diameters to the nearest 0.1 of an inch, placing each in the space allotted to its class, as determined by the rule that each class shall contain all trees whose diameters range from .6 of the one inch to .5 of the next inch higher, inclusive.
3. In the second column enter opposite each D.B.H. tallied the calculated volume of the tree in board feet.
4. In the third column enter the number of trees in each diameter class.
5. When all the trees have been tallied, add the actual D.B.H. measurements in each class as recorded in the first column, and divide by the total number of trees in the class as recorded in the third column to obtain the average D.B.H., and record it in the fourth column opposite its diameter class.
6. In a similar way add the separate volumes in each class as recorded in the second column, and divide by the number of trees in the class to obtain the average volume, and record in the fifth column.

B. *Plotting.*

7. On a sheet of cross-section paper lay off diameters (D.B.H.) and volumes as co-ordinates. Determine first which will be abscissæ and which ordinates and be careful to select values for each commensurate with the limits of variation in the data and the size of the cross-section paper.
8. Plot the average values as determined and recorded in the tables, and enter beside each plotted point the number of trees it represents.

9. Connect the consecutive average points by fine straight lines.
10. Draw a free-hand curve, giving weight to the various points according to the number of trees represented, and smooth off the curve with a spline or other curve rule.
11. Read off from this curve the volumes for whole inches as indicated, and tabulate in one corner of the sheet of cross-section paper.
12. Label the exercise and indicate the species, forest type, locality, total number of trees used, and date.

D. *References.*—Numbers 31, 32 and 36.

PROBLEM 17. (Office.) THE CONSTRUCTION OF *a Full Stem Cubic Foot* VOLUME TABLE BASED ON *D.B.H. and Total Heights.*

METHOD.—Averaging the values first and then plotting the averaged values. For this problem diameters will be taken in 2-inch classes, and heights in 20-foot classes. (Ordinarily heights are taken in 10- or 16-foot classes.)

DIRECTIONS.

A. *Data Required.*—Determine first just what field measurements are necessary for this problem. They differ slightly from those of Problem 16. Ask the instructor if you are right before proceeding.

B. *Use Data Series I,* or the data collected in the field in Problem 6.

C. *Method of Procedure.*

I. *Tabulation.*

1. Prepare a blank form for tabulation like the following:

Two-inch D.B.H. Classes	20-FOOT HEIGHT CLASSES									
	80		100		120		140		Etc.	
	D.B.H.	Volume	D.B.H.	Volume	D.B.H.	Volume	D.B.H.	Volume	D.B.H.	Volume
12″ Class 11.1″ to 13.0″										
14″ Class 13.1″ to 15.0″										

Each diameter class will be understood to include all trees from .1 over the whole inch of one diameter to the whole inch of the second higher diameter inclusive; *i.e.*, the 12-inch class includes all trees

from 11.1 inches to 13.0 inches inclusive; and all height classes from 9 feet below to the even 10 feet above the value indicating the class; *i.e.*, the 80-foot height class includes all trees from 71 feet to 90 feet inclusive.

2. Record the D.B.H. and computed volume of each tree in the space allotted to it according to its D.B.H. and total height. Tally D.B.H. in inches and tenths, and full stem volume in cubic feet and tenths.
3. When all the trees are tallied, determine the total diameter and total volume for each diameter-height class by adding the recorded values and divide each by the total number of trees added to obtain the average diameter and average volume of that class.

II. Plotting

A new feature in plotting the values for this exercise arises which has not been explained heretofore. (See Problem 8.) Instead of having one dependent and one independent variable we now have two independent variables namely, diameters and heights; and the volumes as the one dependent variable. Hence three distinct values must be considered. Since a single plotted point on a piece of cross-section paper cannot express more than two values it now becomes necessary to draw a series of harmonized curves by means of which it is possible to express the three values. This is done by first plotting separate "volume-on-diameter" curves for each height class. From the resulting series of curves we obtain the volumes according to the different diameters irrespective of average heights. With the average volumes read from this series of curves we now construct a series of "volume-on-height" curves for the different diameter classes, and from them obtain the final values as follows:

a. Averaging the Diameters.

1. On a piece of cross-section paper lay off diameters as abscissæ and volumes as ordinates. Since several curves must be drawn on a single sheet of cross-section paper it will be well, in order to avoid confusion, to use a scale such that 1 inch on the paper will represent at least $2\frac{1}{2}$ inches in D.B.H. values. It will also aid if the different points of each height class are connected with lines in different colored inks or crayons.
2. Plot a curve for the first height class using each of the average values and average heights under that class; *i.e.*, plot a curve for the 80-foot height class using the D.B.H. and volumes on the tabulation sheet in a vertical column under this class. Besides each plotted point place the number of trees represented. Join the points by fine lines and draw a smooth curve. Label this curve with the height class it represents.
3. In a similar manner, with the same values for abscissæ and ordinates, and on the same sheet of cross-section paper, plot the

values and draw smooth curves for each one of the remaining height classes. Label each. If any of these height classes contain but few or chiefly abnormal trees, the curve for this class must be interpolated between the next higher and lower classes.

4. From each height curve now read the average volume for the respective average diameters in 2-inch classes by taking the reading at every even inch.

b. *Averaging the Heights.*—Up to this point we have evened off the volumes according to the average diameters, irrespective of heights. Hence it will now be necessary to determine what the average volumes will be according to the average heights.

1. On a piece of cross-section paper lay off heights as abscissæ and volumes as ordinates.
2. Now construct a set of curves similar to those constructed under "*a*," except that a separate curve is constructed for each *diameter class*, using the new volumes read from the first set of curves on the average heights. Use for the heights in this plotting the value indicating the class.
3. Read off the values for every even 20 feet and tabulate in the final form as follows:

D.H.B. Classes	Height Classes				
	80	100	120	140	Etc.
12	Volume	Volume	Volume	Volume	Volume
14	Volume	Volume	Volume	Volume	Volume
16	Volume	Volume	Volume	Volume	Volume

4. Label every curve of this exercise completely, and put a legend on the final table showing the type of volume table constructed, the species, the number of trees upon which the table is based, the unit of measure, and the diameter limit used in computing the volumes of the trees.

D. *References.*—Numbers 39, 41, 42, 43, 44 and 62.

E. Discussion.

1. Of what use is a volume table? Can it be applied accurately for securing the value of a single tree? Why, or why not?
2. In what respect would the method of procedure, outlined above, be varied if the table should be constructed in board feet instead of cubic feet?

3. What is the difference in the data required for the construction of a table based on D.B.H. only and one based on D.B.H. and total heights?
4. Which of the two tables would be the more accurate and why? Which would be easier to use?
5. How many trees would ordinarily be considered the minimum for a good D.B.H. only volume table? For a D.B.H. and total height table?
6. Outline step by step and in detail the method of procedure in a manner similar to that used in Problem 17 for making a table based on D.B.H. and number of 16-foot logs.
7. What are the chief details in which the construction of a table based on D.B.H. and merchantable lengths differ from the method of procedure outlined in Question 6?
8. Describe briefly how a cordwood table based on D.B.H. would be constructed.
9. Describe briefly how a tie table based on D.B.H. would be constructed.

PROBLEM 18. (Office.) The Construction of a Table of *Stem* Form Factors Based on *D.B.H. Only.*

Explanation: The object of this problem is to illustrate the method of constructing a table of form factors and to show the difference between such a table and a volume table.

Directions:

A. *Data Required.* Use the data collected in Problem 6.

B. *Method of Procedure.*

1. First compute the full stem volumes of the trees in cubic feet as explained in Problem 13, Illustration I.
2. Divide the computed volume of each tree by the cubic contents of a cylinder whose diameter is the same as the D.B.H. of the tree, and whose height is equal to the total height of the tree. Call the results the "form factor fractions." For determining the contents of the respective cylinders use the tables of Basal Areas in the Appendix and multiply by the heights.
3. From this point on, the method of constructing the table will be the same, step by step, as outlined for Problem 16, except that the expression "form factor fraction" is used in place of "volume in board feet" throughout the exercise.

Note.—For rough work the Schiffel formula may be used for securing the form factor directly without the necessity of first finding the cubic volume and then dividing this volume by the volume of a cylinder. By the Schiffel formula the form factor of a tree is equal to $0.16+0.66\times Q^2$ where Q is the form quotient, which is the D.M.H. divided by the D.B.H., where the D.M.H. equals the diameter at the middle height of the tree.

C. Discussion.

1. What is the difference between a table of form factors and a volume table?
2. What is the difference in their uses?
3. Which is the more practical for ordinary timber estimating?

PROBLEM 19. (Field.) The Construction of a *Merchantable* Volume Table in *Board Feet* Based on *D.B.H. and Number of* 16-*Foot Logs* by the Frustum Form Factor Method.

Explanation.—A method of constructing volume tables based on D.B.H. and log lengths which much lessens the office work involved and which will give a better table with a lesser number of trees has been devised by Mr. Donald Bruce and is described by him in the Forestry Quarterly, Volume X, Number 2 and in the Proceedings of the Society of American Foresters, Volume VIII, Number 3. This method has not gained universal use and its accuracy compared with the usual method of constructing volume tables has not been entirely established. Several tests have, however, shown that excellent results can be obtained with the method. The following problem will demonstrate this method of constructing a volume table.

Directions:

A. *Data Required.*—About 25 trees will be required for Method I and 100 or more for Method II. Use data collected in Problem 6, or trees of different sizes which show the volumes of boles in board feet measured in 16-foot lengths to an 8-inch diameter in the tops selected at random from Data Series I.

B. *Method of Procedure.*

Method I. To construct a volume table with a small number of trees.

1. Tabulate the sizes of the trees to be used in this problem according to the following form:

D.B.H. Inches	No. 16-ft. Logs to 8″ Top Diameter	Volume B.M. to 8″ Top Diameter	Frustum Form Factor

2. Compute the frustum form factor for each tree by dividing the volume of the tree by the volume of the corresponding frustum of a cone as secured from the table of frustums of cones in the Appendix (Table IV). Interpolate in this table the volumes for diameters breast high to 0.1 inch and lengths to the nearest ¼ of a 16-foot log.

3. Find the average frustum form factor by obtaining the sum of the individual form factors of all trees and dividing by the number of trees.
4. Obtain the volume table by multiplying each volume in the frustum table in the Appendix by the average frustum form factor.

Method II. To construct a volume table with a considerable number of trees.

1. Compute the frustum form factor as in Method I.
2. Devise a convenient form of tabulation and group the trees into 5-inch diameter classes. Secure for each class the average frustum form factor.
3. Round off the values of these average frustum form factors by means of a curve.
4. Obtain the final volume table by multiplying each value in the frustum table in the Appendix by the average frustum form factor for the diameter class in which the value is included.

Note.—Should the table in the Appendix giving the volumes of frustums of cones not contain a sufficient range of values it may be extended by the method illustrated in the following two examples:

Example 1. To find the volume of the frustum of a cone with 8-inch top, 10 inches D.B.H. and $1\frac{1}{4}$ logs in length.

Tree: 10 inches D.B.H. with 8-inch top and 1 log in length yields 1 8-inch log containing 32 feet B.M.

Tree: 10 inches D.B.H. with 8-inch top and 2 logs in length yields
1 8-inch log containing 32 feet B.M.
1 9-inch log containing 42 feet B.M.

Total volume........74 feet B.M.

By Interpolation

Tree: 10 inches D.B.H. 8-inch top $1\frac{1}{4}$ logs in length yields $32+\frac{1}{4}(74-32)=$ 43 feet B.M.

Example 2. To find the volume of the frustum of a cone with 8-inch top, 16 inches D.B.H. and 4 logs in length.

Total taper = 8 inches. Taper per log = 2 inches.

Tree yields 1	8-inch log containing	32 feet B.M.
1	10-inch log containing	54 feet B.M.
1	12-inch log containing	79 feet B.M.
1	14-inch log containing	114 feet B.M.
	Total volume.........	279 feet B.M.

C. *References.*—Numbers 33, 34 and 40.

D. *Discussion.*

1. What is gained over Method I by using Method II?
2. Compare the frustum form factor method and the regular method of constructing volume tables as to time required and as to accuracy.
3. How might the table be constructed by averaging according to the number of 16-foot logs as well as according to D.B.H. as explained in Method II?

PROBLEM 20. (Office.) THE CONSTRUCTION OF A TAPER TABLE.

EXPLANATION: Taper Tables show for each D.B.H. the top diameter inside the bark of the respective 16-foot logs (the usual length employed). Such tables can be used in place of volume tables in cruising where the trees are tallied according to the D.B.H. and number of 16-foot logs. This method has an advantage over volume tables in that an estimate can be worked up according to any log rule or any one of the units of log measure. It presents the disadvantage of requiring more subsequent calculations for securing the volume of an estimate than does the use of volume tables.

DIRECTIONS:

A. *Data Required.*—Use data collected in Problem 6.

B. *Method of Procedure.* (Prerequisite study—Reference Number 38.)

1. On a separate sheet of cross-section paper for each 20-foot total height class, lay off heights above the ground as abscissæ and diameters inside of bark as ordinates.
2. Plot all trees in 2-inch D.B.H. classes.
3. For each D.B.H. class plot points representing the D.I.B. at the top end of each 16-foot log section. If possible, plot all curves on one sheet using a different symbol (., x, o, ⊙,) for each diameter class in order to keep the various classes separate.
4. Average points for each 16-foot section of each D.B.H. class, and construct regular curves for each D.B.H. class.
5. Assume an arbitrary stump height (*e.g.*, 3 feet), and read off the D.I.B. values for each 16-foot section.
6. For the same 20-foot total height classes and with the same ordinates but using D.B.H. for abscissae, replot and average the data in separate 16-foot classes above the stump.
7. From the averaged data found in 6, for each 2-inch D.B.H. class plot a series of 16-foot curves above the stump, using the same ordinates and the total heights of trees as abscissae.
8. With the averaged data from 7 now plot a fourth set of curves exactly as was done in 1 and then, with the data thus obtained, plot a fifth set of curves as was done in 6. Retain the data thus obtained in graphic form or read off a set of tables.

SECTION VI—SCALING

PROBLEM 21. (Field.) SCALING LOGS.

EXPLANATION: The method of scaling sound logs free from any defect or malformation is very simple. All it requires is that the diameter inside the bark at the small end of the log and the length of the log be measured and with these two measurements the corresponding volume in board feet may be found on a scale stick or in a table giving contents of logs according to the log rule used. Should the lengths of logs to be scaled be limited to a certain maximum length, logs longer than this length should be scaled in two sections of as nearly equal even-foot lengths as possible, the shorter length to be taken at the small end of the log. The diameter of the section nearest the large end of the log should be increased over the diameter at the small end by an amount corresponding to the taper, estimated for each log. The sum of the volumes of the two sections will give the volume of the log.

However, no method of scaling is accurate unless the sound volume is discounted to allow for defects which may occur in the log. The following formulæ and tables together with an explanation of the method of their use will demonstrate typical methods of allowing for defect in scaling.

Formulæ for Scaling Defect

Pitch Seams

$$DD=\left(\frac{W\times A}{12}\right)\frac{4}{5}=\frac{W\times A}{15} \qquad T=DD\times L$$

W = width of seam across end of log, inches;

A = waste thickness, inches;

12 = dividing factor, to reduce to B.M.

DD = defect deduction per lineal foot in feet B.M.

L = length of defect, feet;

$\frac{4}{5}$ = reducing factor, to allow 20 per cent for sawkerf;

T = total number feet B.M. defect caused by seam.

Pitch Rings

$$DD=\left(\frac{\pi D\times A}{12}\right)\frac{4}{5}=0.2(D\times A) \qquad T=DD\times L.$$

D = diameter of ring, inches;
$\pi=3.14$.

Remaining factors same as for pitch seams.

Rot

$$DD=\left(\frac{W^2}{12}\right)\frac{4}{5}=\frac{W^2}{15}, \qquad T=DD\times L.$$

W = side of a square which can be circumscribed around the defect, inches;

Shingle Bolts

$$V=\frac{E\times L}{144}\times .70.$$

E = area of end of bolt, square inches;
L = length of bolt, inches;
144 = dividing factor to reduce to B.M.;
.70 = per cent of utilization;
V = total number feet B.M. in bolt.

Explanation of Scaling Formulæ

There are various systems of making allowance for the defects which occur in logs but the simplest and most logical is to consider the amount of the defect as equivalent to the piece of lumber which would be lost in sawing it out in the saw mill. As the Scribner rule makes an allowance for sawkerf of $\frac{1}{4}$ inch for each 1-inch board or a deduction of 20 per cent of the volume of the log this deduction should also be taken into account in making the defect allowance.

In the formulæ the defect deduction is first found per lineal foot and then multiplied by the length of the defect as this is the easiest procedure for the scaler to follow in practice as will be explained below for each type of defect.

Pitch Seam.—To determine the amount of defect in a log with a pitch seam or seams the scaler should determine if they show on both ends of the log and whether they are straight or twisted, for the greater the twist the

greater will be the amount of waste. Sometimes a seam at one end of the log will be at right angles to its position on the opposite end. If the seam shows on one end only, the scaler should estimate the length it extends into the log and take as the width of the seam its width as it shows. If the seam shows at both ends of the log the width of the seam should be taken at whichever end it is the greatest.

Measure the width of the seam across the end of the log and the inches of waste that will result from sawing out the seam. Multiply the width of the seam by the thickness of the waste, divide by 12, and multiply the result by $\frac{4}{5}$, which will give the number of feet B.M. defect per lineal foot. Multiply this by the length of the defect and the result will be the total number of feet B.M. defect caused by the seam.*

Pitch Ring.—To determine the amount of defect in a log with a full pitch ring the scaler should first determine if the ring shows on both ends of the log. If it does not show on both ends he should estimate the number of feet it extends in the log, and then measure the diameter of the ring. If it shows on both ends he should average the diameters of the rings on both ends. Care should be used in getting this average diameter in swell butted logs so as to get a fair average, for the ring generally tapers with the swell and if the swell is very great the measured diameter will be too large.

Multiply the diameter of the ring thus obtained by 3.14 to obtain the circumference and then measure or estimate the number of inches of waste necessary to saw out the ring—the inches of waste depending upon the irregularity of the ring. When two rings occur close together a large factor of waste must be taken as no lumber can be cut between the rings.

Multiply the circumference by the thickness of waste, divide by 12 and multiply the result by $\frac{4}{5}$. This will give the number of feet B.M. defect per lineal foot. Multiply this result by the length of defect and the result will be the total number of feet B.M. defect caused by the pitch ring.

Rot.—To determine the amount of defect in a log with center or stump rot, the scaler should first determine if it shows on both ends of the log. If it does not show on both ends he should estimate the number of feet it extends into the log and then measure its diameter. If it shows on both ends he should average the diameters if the rot is uniform throughout the length of the log. Care must be taken with swell butted logs to get an average diameter as the rot usually tapers very rapidly in such logs. When such logs have rot of large diameter at one end and rot of small diameter at the other end it is well to divide the length of the rot into sections and give each section a diameter estimated according to the taper of the rot. Each section would then be treated as a unit by itself and the total of the defect for each would

* Since in scaling with most log rules all material outside the cylinder represented by the top end diameter is considered as lost in slabbing, a defect which shows at the butt end of a log should never be taken as larger than the top diameter of the log unless the log is scaled in two sections, as explained in Problem 12. In this case the defect at the butt of the log should not be taken as larger than the top diameter of the butt section.

give the total defect for the log. It will be noted that the rot formula is similar to the pitch seam formula except that the width of the defect is taken as equal to the diameter of the rot.

Slab.—Western red cedar logs in the course of handling very often split up into slabs which can not be accurately scaled as logs. The method used on the Pacific Coast in this case is to estimate the volume of the slab in shingle bolts and reduce this volume to feet B.M. by the formula given above. A "shingle bolt" in the formula is a piece 52 inches in length with roughly, equilateral triangular ends, the sides of this triangle being 12, 14, 16, or 18 inches in length. To determine the number of feet B.M. in a shingle bolt, first measure the end and compute the area of it in square inches, then multiply by the inches in length and divide by 144. Multiply this result by .70 and the result will be the number of feet B.M. in the bolt.

Example: How many feet B.M. in a bolt 52 inches in length which has a triangular cross section 18 inches on a side?

$$\frac{\text{Area of triangle (18 by 18 by 18)} \times 52}{144} \times .70 = 35 \text{ feet B.M.}$$

Miscellaneous Defects.—The formulæ just given for seams, rings, and rot can be applied to nearly all other interior defects. There are, however, several other types of defects to which they do not exactly apply, such as crook, cat face, sap rot, worms, broken ends, etc. Allowance for crook can be made by a lump percentage of the total contents of the log or by deducting the equivalent of the piece of lumber which it is visualized would be lost. No allowance is made for cat face or similar side defects unless they extend inside the cylinder represented by the top diameter of the log, in which case the equivalent of the piece of lumber lost should be computed and deducted. Allowance for sap rot will be made by scaling the log with a diameter inside the exterior decay. Worms and broken ends can be allowed for by reducing the length of the log sufficiently to eliminate the defect.

Method of Using Scaling Tables

In order to simplify the application of the method to actual scaling, by means of the scaling formulæ, the tables on page 42 have been computed to show the defect per lineal foot for the most common sizes encountered in scaling. A copy of these tables should be carried by the scaler for reference at all times.

Included with the scaling tables is a legend for use in indicating on the scaling sheet (Form 5) the kind of defect found in each log. This legend may be used as follows:

If a log has a pitch ring, use the letters P. R. as shown in legend instead of writing the words in full.

If a log has a pitch seam and ground rot, use the letters P. S. and G. R.

If a cedar slab is scaled, place the letters Sl in the defect column.

TABLES FOR SCALING DEFECT

Legend for Defect

P.R. Pitch ring
P.S. Pitch seam
S. Shake
Sl. Slab
Sp. Split
Sh. Shatter
C. Conk
Cr. Crook
Ch. Check
Ck. Chunk
R. Rot in cedar
G.R. Ground or stump rot
W. Worms
B. Broken end
O. L. Overlength
Pk. Punk or sap rot
Y. Crotch

Shingle Bolts

No. of Bolts	Size 18×18	16×16	14×14	12×12	Length
	Bolts per Cord 20	25	33	44	
	Board Feet				
1	35	28	21	16	4′ 4″
2	70	56	42	32	8′ 8″
3	105	84	63	48	13′ 0″
4	140	112	84	64	17′ 4″
5	175	140	105	80	21′ 8″
6	210	168	126	96	26′ 0″
7	245	196	147	112	30′ 4″
8	280	224	168	128	34′ 8″
9	315	252	189	144	39′ 0″
10	350	280	210	160	43′ 4″

Diameter or Width	Pitch Rings			Pitch Seam			Rot
	Waste, Thickness Inches						
	3	4	5	2	3	4	
	Defect per Lineal Foot						
6	4	5	6	1	1	2	2
7	4	6	7	1	1	2	3
8	5	6	8	1	2	2	4
9	5	7	9	1	2	2	5
10	6	8	10	1	2	3	7
11	7	9	11	1	2	3	8
12	7	10	12	2	2	3	10
13	8	10	13	2	3	3	11
14	8	11	14	2	3	4	13
15	9	12	15	2	3	4	15
16	10	13	16	2	3	4	17
17	10	14	17	2	3	5	19
18	11	14	18	2	4	5	22
19	11	15	19	2	4	5	24
20	12	16	20	3	4	5	27
21	13	17	21	3	4	6	29
22	13	18	22	3	4	6	32
23	14	18	23	3	5	6	35
24	14	19	24	3	5	6	38
25	15	20	25	3	5	7	42
26	16	21	26	3	5	7	45
27	16	22	27	4	5	7	49
28	17	22	28	4	6	8	52
29	17	23	29	4	6	8	56
30	18	24	30	4	6	8	60
31	19	25	31	4	6	8	64
32	19	26	32	4	6	9	68
33	20	26	33	4	7	9	73
34	20	27	34	4	7	9	77
35	21	28	35	5	7	9	81
36	22	29	36	5	7	10	86

Pitch Ring, Pitch Seam and Rot Tables.—These tables have been computed by use of the defect formulæ explained in the first part of this problem. In the pitch ring table the first column gives the diameter of the ring, the figures below "Waste Thickness" give the inches waste necessary to saw out the ring and the figures under columns 3, 4, 5 show the number of feet B.M. of defect per lineal foot. The pitch seam table similarly shows the defect for different waste thicknesses and widths. The rot table shows the defect for different average diameters. In each case the defect per lineal foot should be multiplied by the total length of the defect and the result subtracted from the full scale.

Example: If a log has a pitch ring 20 inches in diameter and a waste thickness of 4 inches, the defect in board feet per lineal foot will be found in the column headed "4" under "Pitch Rings" opposite 20 in the "Diam." column, which in this case is 16 board feet. Multiply this defect per lineal foot by the distance the pitch ring extends into log and the result will be the total number of feet B.M. defect caused by the ring.

Example: If a log has a pitch seam 16 inches in width across the end of the log and a waste thickness of 2 inches the defect in board feet per lineal foot will be indicated in the column headed "2" under "Pitch Seam" opposite 16 in the "Diam." column, which in this case is 2 board feet. Multiply this defect per lineal foot by the distance the seam extends into the log, and the result will be the total number of feet B.M. defect caused by the seam.

Example: If a log has a uniform rot 16 inches in diameter, the defect in board feet per lineal foot will be indicated in the column headed "Rot" opposite 16 in the "Diam." column, which in this case is 17 board feet. Multiply this defect per lineal foot by the distance the rot extends into the log and the result will be the total number of feet B.M. defect caused by the rot.

Shingle Bolt Table.—By means of the formula for securing the contents of shingle bolts the table above has been computed to show the contents in board feet of bolts 52 inches long with triangular ends 18×18×18, 16×16×16, 14×14×14, and 12×12×12 inches. Under each column heading giving the size of the bolt is shown a figure representing the number of bolts of that size contained in a cord and in the table below is shown the board foot contents of any number of bolts from one to ten inclusive. In the last column under "length" is shown the length in feet corresponding to the number of bolts indicated in the first column.

In using this table for scaling slabs the scaler should first ascertain what size bolts the cross section of the piece is equivalent to and then estimate the number of that size bolts contained in the piece. The number of board feet in the piece may then be secured by referring to the shingle bolt table.

Should the cross section of the slab be larger than an 18×18×18 bolt it may be divided into bolts of two sizes (*i.e.*, 18×18×18 and 12×12×12, etc.), and the number of such bolts and their equivalent board-foot contents secured.

Example: A slab triangular on the ends measuring 18 inches on the side and 40 feet in length contains nine bolts. The scaler looks in column "No. of Bolts" and finds 9; then, in column "18×18" opposite "9," in the first column, he finds that the slab contains 315 board feet. If the piece contained 9 bolts 14×14 and 9 bolts 16×16, the table indicates that 9 bolts 14×14 contain 189 board feet, and 9 bolts 16×16 contain 252 board feet, and the sum of these two gives the total number of 441 board feet in the slab.

Directions:

A. *Parties.*—Each man will work by himself in this problem.

B. *Equipment Required.*

1 scale stick;
1 blue lumber crayon;
1 field note book supplied with Form 5;
1 copy of table for scaling defect.

C. *Method of Procedure.*

1. In an area in which logs are available select a specified number of logs for scaling.
2. Number the top end of each log consecutively and place this number in the proper column in the form in order that the instructor may check the scaled contents.
3. Scale the sound contents of each log in accordance with directions given in Problem 12. Estimate or actually measure the taper of a log when it is divided into two or more sections in applying the maximum scaling length.
4. Inspect the log carefully to ascertain whether it has any defects and if it has make the deductions by means of the scaling table in accordance with the principles outlined above.
5. Tally the net scale in the proper column. In the "Defect Column" show the defect by symbol and amount. If the scaling is done by the Scribner Dec. C. Rule, both the defect and the net scale should be tallied to the nearest ten feet B.M. and the zero to show the full scale added only to the total net scale at the bottom of the page.

D. *References.*—Numbers 45, 46, 47, 48, 53 and 54.

SECTION VII—DETERMINATION OF THE CONTENTS OF STANDS

EXPLANATION: This section has been outlined especially with reference to Pacific Coast timber. Very slight modifications to suit the needs of the different sections of the country will, however, make it available for use anywhere. The blank pages at the end of the problems may be used for noting such modifications. The work has been arranged to illustrate several methods of cruising, so as to allow the student to compare them, and to give him practice in estimating the total volumes of trees and stands by ocular estimate.

PROBLEM 22. (Field.) OBTAINING THE CONTENTS OF A SMALL TRACT OF TIMBER BY DIFFERENT METHODS.

DIRECTIONS:

A. *Parties.*—Men will be organized in two-man crews, each man alternating as tallyman and as cruiser.

B. *Instruments.*

1 pair tree calipers.
1 compass.
1 hypsometer.
1 field notebook, supplied with Forms 1, 3 A, B and 4 A, B.

C. *Method of Procedure.*

1. Select a representative area in the stand, and with the aid of the compass and paced distances run out a square acre (208.7 feet on a side).
2. Secure the volume of the acre tract by the following five methods:
   (*a*) Ocular estimate.
   (*b*) Commercial cruising method.
   (*c*) D.B.H. volume table method.
   (*d*) Diameter-height volume table method.
   (*e*) Spaulding rule method.

   These methods should be carried out in the following way: Each of these methods, except (*c*) and (*d*) which may be combined in the field, should be worked out separately in the order given, and the volume computed on the ground before proceeding with the next

method, in order best *to compare* them. Make no deduction for defect or breakage and include all standing live or dead trees above 12 inches D.B.H. since the object of the exercise is to compare total volumes.

(*a*) Ocular estimate.

Before measuring or counting *any* of the trees make an estimate of the total volume of the tract. The succeeding methods will show the accuracy of your estimate. Use Form 1.

(*b*) Commercial cruising method.

Count all the trees on the tract, and estimate the volume of the average tree. Multiply this volume by the number of trees to secure the total volume of the stand. Check the method by actual measurement of what is judged to be an average tree, calipering its D.B.H., measuring the height with the hypsometer, and computing the volume by the Spaulding Rule of Thumb (See Problem 15, Illustration 1, Method I). Use Form 1 for recording the measurements and estimate.

(*c*) D.B.H. volume table method.

Caliper the diameter breast height outside the bark of all trees on the tract. Compute the volume of the tract by use of the volume table constructed in Problem 16, or any other volume table based on diameters breast high only, which would be applicable to the conditions. Use Form 3 A for recording the measurements and estimate.

(*d*) Diameter-height volume table.

Caliper the diameters breast high outside the bark, and estimate the total heights of all trees on the tract. As a check measure with a hypsometer the heights of the first trees taken. Compute the volume of the tract by use of the volumes given in Tables V–VIII in the Appendix, or any other tables based on D.B.H. and total heights that would be applicable to the conditions. Use Form 4 for recording the measurements.

(*e*) Spaulding rule method.

Tally the D.B.H. inside the bark and the length of all trees on the tract from the breast height point to a point on the bole where the D.B.H. is equal to $\frac{1}{2}$ D.B.H. (outside bark). Measure this length by means of a hypsometer. Compute the volume of the tract by the Spaulding rule of thumb explained in Problem 15, Illustration 1, Method I. Use Form 3 A.

D. *References.*—Numbers 14, 56, 58 and 60.

E. *Discussion.*

1. Which method is most accurate?
2. Which method is the most rapid?
3. Which method would you choose to cruise a given tract? Why?
4. Can the first two methods be safely used by inexperienced men?

PROBLEM 23. (Field and Office.) CRUISING WITHOUT THE AID OF A VOLUME TABLE.

EXPLANATION: The object of this problem is to illustrate a method of cruising a large tract of timber when there are no volume tables available.

DIRECTIONS:

A. *Equipment Required.*

1 Forest Service staff compass, or hand compass when the former is not available.
1 pair of tree calipers.
1 field notebook with Forms 3 A and B.

B. *Parties and Organization.*

Men will be organized in two-man parties, one man acting as compass- and tallyman and the other as caliperman. Each crew will cruise a quarter section tract. One man will act as cruiser and the other as compassman on the first eighty acres covered, and the second man as cruiser for the second eighty. In this way each man will cruise one-half of the tract. The men should assist each other in working up the data, but each will hand in only the data for the area he has cruised.

C. *Method of Procedure.*

The estimate will be obtained by running two strips, four rods wide, through each "forty"; on each strip diameters breast high of trees 10 inches and over will be tallied; the heights will be obtained from a height curve constructed from data collected in the field as suggested under Section II; the volumes will be computed by means of the Spaulding Rule of Thumb.

Part I. Running the Strips

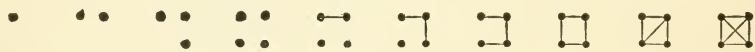
The compassman will pace, run the compass line, and tally the sizes called off by the cruiser who will take the D.B.H. to the nearest even inch of all trees 10 inches and over on the four-rod strip.

The cruiser should be careful to look out for defects in the trees calipered. As he approaches a tree when at a distance from it where he can see the whole stem, he should look up the hole for conk, fungus or other defects. The volumes

of trees showing conk should be discounted by reducing the sound volume 50, 75 or 100 per cent, according to the cruiser's judgment as to the extent of the fungus attack. Trees with other defects such as fire-scars, hollow butts, broken tops or any other visible defects should be reduced in volume by the proper percentage estimated in the field for each tree tallied. All snags which have not been dead over four years and are apparently sound should be tallied. All windfalls which originally stood upon the strip and which are sound enough to produce lumber should be tallied. In this respect it should be remembered that cedar remains sound for a great many years and that cedar windfalls can hence be taken much more closely than any other species. The taper of swell-butted cedars must be taken into account by reducing the D.B.H. several inches so as to give the cedar no more swollen butts than normal fir trees, as otherwise the Spaulding rule will give too high volumes. Defects such as pitch, spike tops, butt rot, shake, and all other hidden defects and breakage will be discounted by deducting a lump percentage from the total volume at the end of work. This percentage should be estimated by the cruiser in the field. Instructions for making discounts for defects must be given by the instructor on the ground. Special directions cannot be given here.

For tallying, the cruising sheet (Form 3 A) will be used which has the page divided into columns for different species. One column will be used for tallying each species by means of the regular dot system as follows: The trees are tallied by dots and lines, in blocks of ten, as indicated in the following table, which shows the marks corresponding to different numbers.

1 2 3 4 5 6 7 8 9 10



Dead trees or snags which have merchantable contents should be tallied in the same column with the living trees with an "x" instead of a dot to distinguish them. Defective living trees should be tallied in the same columns with the sound, but should be kept separate by tallying them with the following symbols:

For 10 per cent deducted from the sound volume:
For 25 per cent deducted from the sound volume:
For 50 per cent deducted from the sound volume:
For 75 per cent deducted from the sound volume:
For a tree tallied by mistake: ⊙

Dead defective trees should be tallied in a similar way, except that an "x" will be used in place of the dot. The number of snags over 12 inches in diameter without merchantable contents may be tallied in the column provided on the right hand side of the sheet should the purpose of the cruise require these data. The percentage of estimated hidden defect for each species and the breakage for the whole "forty" should be tallied in the proper spaces at the bottom of the sheet.

Each forty cruised will be tallied on a separate sheet, and the tallyman should hence change sheets when a forty has been completed, taking care that the forty number, section number, and direction of course at the top and in the lower right-hand corner of the tally sheet are completely filled out so that the forty can always be located. The different species will be tallied in separate columns.

Part II. Securing the Height Data

Since heights will not be tallied in the field it will be necessary to construct a height curve from data collected for each species. For this purpose sufficient time should be taken during the cruising to obtain the necessary measurements. These measurements are made on down trees and as many should be taken as possible. For each down tree measure the D.B.H. outside of bark, width of bark at D.B.H. or as near this point as possible, and the merchantable length from stump to $\frac{1}{2}$ D.B.H. outside bark.

Part III. The Forest Description

While running the strips, or at any other convenient time, the cruiser should take notes to be used as a basis in writing a detailed forest description of the tract. Use Form 3 B. All information called for on the form should be obtained.

Part IV. Office Computations

The estimate will be worked up and totaled by 40-acre tracts. The volume of all trees above 22 inches D.B.H. except hemlock will be computed in feet B.M. by the method explained in Problem 15, Illustration 1, Method II. Hemlock 16 inches D.B.H. and over will be computed in feet B.M. All fir from 16 inches to 22 inches D.B.H. inclusive will be computed as piling, and all cedar from 10 inches to 22 inches as poles, by simply noting the number of pieces. All fir and hemlock from 10 inches to 14 inches D.B.H. inclusive will be computed in ties. This will necessitate an estimate of how many No. 1 ties ($6'' \times 8'' \times 8'$) or No. 2 ties ($6'' \times 6'' \times 8'$) an average 10-, 12- or 14-inch tree will contain.

The following data should be handed in by each party:

(1) A height curve and a volume curve both on D.B.H. for each species, together with the accompanying tables read from them.

(2) All tally sheets.

(3) Summary sheet, showing the cruise by species for each forty and totals for the tract.

(4) A forest description of each eighty. Arrange all in neat, logical order.

D. *Reference.*—Number 56.

NOTE.—This page should be used for noting special instructions, relating to the preceding exercise, in order to meet the conditions of a particular tract or region.

PROBLEM 24. (Field and Office.) CRUISING WITH THE AID OF A VOLUME TABLE.*

EXPLANATION: The object of this problem is to illustrate a method of cruising a tract of considerable size with volume tables showing values for trees of different diameters and total heights.

DIRECTIONS:

A. *Equipment Required.*

1 hand compass or Forest Service Compass and Staff.
1 pair of tree calipers.
1 hypsometer.
1 field notebook with cruising Forms 4 A and B.

B. *Parties and Organization.*

The same organization as outlined for Problem 23 will be followed in this exercise.

C. *Method of Procedure.*

The estimate will be obtained by running four strips four rods wide through each forty. On each strip the diameters breast high and the total heights of all trees 10 inches and over in diameter will be tallied. The volumes will be obtained by means of the volume tables given in the Appendix or any other tables based on diameters breast high and total heights, applicable to the conditions.

Part I. Running Strips

The compassman will pace, run the compass line and at the end of each acre (4 rods wide by 40 rods long) cruised will see that the cruiser changes the tally sheets. If the object of the work requires a topographic map the compassman will make such a map while the cruiser tallies the trees. If no *topographic* map is required he need only run the compass line and pace the distances unless the area of the stand be irregular in which case he should *plat a diagram* to scale on Form I of the field notebook showing the shape of the tract, boundaries of the timber, limits of forest types, location of burns or other features affecting the forest cover.

The cruiser will tally the diameters breast high and total heights of all trees 10 inches and over in diameter. At the end of each acre he will carefully fill out on the reverse side of the tally sheet the acre number, direction of course, section number, etc., which will locate the acre, and he will then change tally sheets.

Tallying will be done on Form 4 A, using the thirty-foot height classification given on these sheets, *i.e.*, up to 75 feet, 75 to 105, 106 to 135, 136 to 165, 166 to 195, 196 to 225, 226 to 255, and from 256 feet up. In case the volume table used

* As in Problem 23, this exercise will need to be modified if used anywhere except in the Pacific Coast region. The modifications may be noted on the blank page following the problem.

is constructed with a different classification of heights than that given here, the same height classes used in the table should be used in cruising. The dot system of tallying described in the previous exercise should be used. Each of the species will be tallied separately in one of the three sets of columns provided on the tally sheets. Should more than three species be found on the area to be cruised the three species found in greatest number should be tallied in the columns provided and other species tallied at the bottom of the sheet by name and size, *i.e.*, a white pine 35 inches D.B.H. 125 feet high would be tallied W. P. -35 -125, or if it had 10 per cent defect, W. P. -35 -125 -10 per cent.

Deductions for all defects which would affect the amount of lumber which can be cut from the tree, will be made exactly as outlined in Problem 23, except that the diameters of swollen-butted cedars need not be reduced unless the swelling is excessive.

Part II. Office Computations

After completing the field work the next step is to compute the contents in board feet of each species on each tally sheet. If a considerable amount of this kind of work has to be done a multiplication volume table should be made. This is made by expanding the volume table so that it will show for each different D.B.H. and height class the volumes of trees from one to ten in number. For example, Volume Table Number V in the Appendix if converted into a multiplication volume table would have the following form:

D.B.H.	to 75			76–105				Etc.
	1 tree	2 trees	Etc., to 10 trees	1 tree	2 trees	3 trees	Etc., to 10 trees	
10	80	160		100	200	300		
12	100	200		140	280	420		
Etc.								

With such a table the volume of any number of trees up to ten may be read off at a glance or the volume of any other number of trees secured by a short computation and the work will be much hastened; *i.e.*, the volume of 13 trees would be the sum of the volume of 10 trees and 3 trees.

Using the multiplication volume table one man should call off the number of trees in each D.B.H.-height class of a certain species to the other man of his party who will immediately give him their volume as read from the table. The first man will enter this volume on the tally sheet and total for each species, or better still will enter the volumes, as called out, in an adding machine and secure the total with the machine. The totals for each species should be entered at the foot of the proper column and should be kept separate for the sound live trees, the defective live trees, and the sound and defective dead trees. In the case of the defective trees the totals should have defect properly discounted.

Each distinct total for each species should then be multiplied by 5, since the strips tallied covered 20 per cent of the total area. These totals should then be reduced by the percentage estimated in the field for hidden defect and breakage. The total of each species and the grand total of all species for each forty should then be computed by adding together the totals on each tally sheet included in the forty.

Should any acre tallied be of full size but the tract it represents of irregular size, the area of the fractional tract should be obtained before the estimate is calculated. This can be done with a planimeter by measuring the plat made in the field, or by estimating the number of squares on the plat included in the irregular tract and calculating their equivalent area. The volume of this tract is then secured by multiplying the volume of the acre tallied by the number of acres in the irregular tract. For example, in a 20 per cent cruise each acre tallied represents 5 acres and the total cruise were the area perfectly regular, would be secured by multiplying the volume of the acre tallied by 5. Suppose, however, that one corner of the tract is logged off and from the plat it is found that 2 acres contain no timber. The volume of the acre sheet would then be multiplied by 3 instead of 5.

If neither the acre tallied nor the tract it represents were complete the volume of the equivalent full acre should be found by dividing the volume of the fractional acre by its area expressed in tenths of an acre. The volume of the fractional tract would then be found as explained above. For example, the last tally sheet covers but 0.8 of an acre and it represents but 3 acres instead of 5 as normally. The volume of the fractional acre would then be divided by 0.8 to reduce the fractional acre to terms of a whole acre. This volume would then be multiplied by 3 to find the volume of the tract. The same method might also be applied to the forty as a unit instead of the acre.

Each party, upon the completion of the work, should hand in all tally sheets and a summary sheet showing the total stand by species for each forty and the grand total for the whole area.

D. *References.*—Numbers 37, 55, 57, 59, 61 and 63.

E. *Discussion.*

1. How would the method of procedure outlined above be modified if the volume tables to be used were based upon merchantable lengths instead of total heights?
2. How would the method of procedure be modified if the heights of the individual trees were not tallied but the trees on each forty were given one of three height classifications and the volume tables used were constructed with similar height classifications.
3. Discuss the respective merits of deducting for defect by a percentage for each individual tree or by a lump percentage to cover all defects for each acre cruised.
4. What is the advantage in changing tally sheets at the end of each acre rather than at the end of each forty?

5. Discuss the advantages and disadvantages of using a correction factor to adapt the cruise to stands outside of the strip cruised which have a greater or a lesser volume per acre than the stand on the strip.
6. What criticisms of the method of procedure given above for carrying on the office work might be made and why?

NOTE.—This page should be used for noting special instructions to be given by the instructor in order to meet the conditions of a particular tract or region.

SECTION VIII—GENERAL GROWTH STUDIES

Explanation.—Studies in the growth of trees are made chiefly for the purpose of determining the number of years required for trees to become merchantable in size, for the prediction of future yield in volume, as a basis for silvicultural practice and as steps in organizing forests for continuous timber production. Studies are made on growth in diameter, height, basal area, and volume. These may be made for individual trees or as an average for small groups or even for extensive areas. As a basis for predicting the volume growth of stands studies are usually made in terms per acre and are then known as yield studies. Growth in diameter and height form the direct basis for the volume and yield studies.

In many studies it is necessary to distinguish growth with reference to time. Thus we have (C. A. G.) Current Annual Growth, that for any one specific year; (M. A. G.) Mean Annual Growth, the average annual rate of growth during the life of the tree; the (P. G.) Periodic Growth, the rate for any specific period of years. In some problems, particularly the prediction of growth in the future, we have growth per cent, which is determined by means of a simple interest formula that shows the per cent of increase in relation to the present size of the tree or stand.

Prerequisite Study.—Before taking up the exercises included in this section the student should review the general method of collecting data for growth studies, Problem 7.

Caution.—In all growth studies it should be remembered that the number of measurements required both as to kind and quantity will vary with the specific problem to be solved. Since separate studies must be made for trees growing under different conditions, a completed curve or table will have no value unless it is labeled with all the conditions of growth. This is even more important in growth studies than in volume studies. All of the points enumerated in the outline below should be considered in the title or label for each distinct growth study, though not all need be included because some conditions may be wholly obvious from some others already stated. For example, if a study had been made of the growth of Virgin Yellow Pine in Eastern Oregon, it would be practically obvious that it represents the growth in an uneven-aged stand.

*Points to be Considered in Connection with Title.**

1. *The general problem.*
2. *Species.*

* Those italicized should appear in the title of each problem.

3. Even- or uneven-aged stand.
4. Pure or mixed stand.
5. *Forest type.*
6. *Soil or site quality.*
7. Density.
8. *Number of trees upon which the study is based.*
9. *Locality.*
10. Virgin or second growth.
11. *Date.*
12. *Be sure to indicate units of measurement* (feet, inches, B.M., etc.) *and kind of growth* (Dia., Vol., P. A. G., C. A. G., etc.) *on all curves and tables.*

PROBLEM 25. (Field.) THE DETERMINATION OF THE TOTAL AGES OF TREES.

EXPLANATION.—In this problem it is assumed that we have determined the ages at the stump of a large number of trees. In order to determine the total ages of these trees it would be necessary to cut the trees near the surface of the ground because that is the only portion where a growth ring has been added each year from the time the tree was a one year old seedling, several inches high, to the time of cutting. To cut large trees near the surface of the ground would, of course, be impracticable. Hence the ages at the stumps must be corrected by a separate study of height growth on seedlings whose total heights vary about as the stump heights.

ILLUSTRATION.—To determine the total ages of the trees analyzed in Problem 7.

DIRECTIONS:

A. *Parties.*—Each student can work to advantage by himself.

B. *Equipment.*

1 sharp pocket knife.
1 rule or tape graduated to inches.
1 hand lens.
Pencil and field notebook with Form 1.

C. *Method of Procedure.*

1. Select trees of the same species and of about the heights of the stumps and under the same conditions of growth as those whose total ages it is desired to find.
2. With the pocket knife cut from 10 to 15 seedlings at about one inch from the surface of the ground. The heights should vary about as the heights of the stumps of the trees whose ages are to be corrected.
3. Determine the age and height of each. In conifers this may be done by counting the whorls of branches and checking by ring counts:

in hardwoods usually ring counts alone can be used, though often these may be checked by the annual nodes, or terminal bud scars. Record the measurements in a table of two columns with ages opposite heights.

NOTE.—When the annual nodes are conspicuous it is often possible to obtain a number of height measurements from each individual seedling as follows:

1. After the total age and the total height of a seedling are determined, subtract one from the total age and measure the height to the first annual node below the tip.
2. In a similar manner determine the values with reference to each of the remaining annual nodes.

(The same may be done by cutting the seedlings into 6-inch lengths and constructing a height growth table. See Problem 29.)

4. On a sheet of cross-section paper (Form 1 of Field Notebook) lay off heights as abscissæ, and ages as ordinates. Plot the values, in half-foot height classes, draw a smooth curve and read off a table showing the average ages of the heights for each 0.5 of a foot, and label.
5. Apply this table directly to the stump ages as follows, and record in the proper spaces in the data blanks.
   (*a*) Look up the stump height of each tree on the front of the Analysis Blank (Form 2 A).
   (*b*) Determine in the table just constructed the number of years it took the tree to grow to stump height.
   (*c*) Add this number of years to the age at the stump and record as "Total Age."

PROBLEM 26. (Office.) THE DETERMINATION OF *Diameter Growth* IN *Even-aged* STANDS.

EXPLANATION.—The object of this exercise is to illustrate the fundamental principles involved in *all diameter* growth studies in *even-aged stands*. In all cases tables are to be prepared that will show the average diameter a tree may be expected to attain at some one or more points (certain prescribed distances above the ground) along the bole of the tree. The growth at each of these points is determined by a separate study. The method of procedure will be practically the same for all problems involving diameter growth in even-aged stands, as that outlined in the illustration given below. It is customary to make these studies in ten-year age-periods.

ILLUSTRATION.—To Construct a Table of Average Diameter Growth *at the Stump* for Even-aged Stands, *not Thinned*.

A. *Data Required.*—Stump analysis and total ages. Use Data Series III.

B. *Method.*—Plotting the values before averaging.

NOTE.—When this problem is completed do not erase any of the plotted points. They will be of use in succeeding problems. When these data are not to be used

for other purposes it may be more convenient to average before plotting, especially when a large number of trees are used. In this case rule a large sheet of paper so that there will be one vertical column for each age from one year to the age of the oldest tree. Record the radius measurements in their proper age columns, average and finally even off by means of a curve.

C. *Method of Procedure.*—(Using method of plotting before averaging.)

1. Ages in this case are the independent variables, diameters the dependent variables; hence, lay off the cross-section paper with ages in ten-year periods on the abscissa axis, and diameters in inches on the ordinate axis. Label.
2. Before plotting the values from any analysis sheet it should be checked according to the instructions for the tallyman, Problem 7. If it does not check do not use it. All data in this book supplied for use with this problem have been checked.
3. Determine the respective values of the points to be plotted as follows, and plot them accordingly:
   (*a*) The successive diameter values by multiplying the radius measurements, as recorded, by 2.
   (*b*) The age corresponding to the first radius measurement is taken as recorded in the upper left-hand corner of the space allotted to the first decade. The succeeding ages are determined by adding 10 years to the age of the first decade for the age of the second decade, and 10 years more for each successive decade; or the age at any decade is equal to: [(No. of the decade minus 1) times 10] plus number of years in the first decade. This, however, gives the age at the stump and not the total age of the tree; hence, in order that our study may be based on the *total age*, it will be necessary to add also the number of years it took the tree to grow to stump height. The formula then becomes: The total age for any decade measurement equals [(No. of the decade minus 1) times 10] plus the number of years in first decade plus the number of years required to grow to stump height. During the actual process of plotting it is necessary to determine this value only for the first point to be plotted. The values (ages) of the succeeding abscissæ can be determined very rapidly by simply adding ten years to each preceding value.
4. When all the values are plotted average for each ten-year period as follows:
   (*a*) The average ages: By averaging separately, in a horizontal direction, all plotted points in each ten-year period, letting 0 to 10 inclusive represent the first period, 10.1 to 20 inclusive the second, and so on.
   (*b*) The average diameter: By averaging separately, in a vertical direction, all points in each age period as in (*a*).

5. Draw a smooth curve and read off a table showing the average diameters at the end of each ten-year period.
6. Label.

PROBLEM 27. (Office.) THE DETERMINATION OF GROWTH IN *Uneven-aged* STANDS.

EXPLANATION.—Growth in uneven- or many-aged stands differs from growth in even-aged stands in that the individual trees grow more nearly like the trees of a certain diameter than they do like trees of a certain age. Hence, except when it is desired to determine the mean annual growth of trees, growth studies in uneven aged stands are usually based on diameters (D.B.H.) instead of ages. This holds true and, as described below, is applicable to all kinds of growth in uneven-aged stands. The object, then, is to determine how fast a tree of a certain diameter is growing, either in diameter, height, volume, or other dimensions. This immediately makes it evident that when a tree of one diameter class has grown to the next higher diameter class it has a different rate of growth. Our problem then becomes one of determining first of all the periodic annual growth for each diameter class and from this the number of years required to grow one unit; *i.e.*, in diameter, one inch.

The independent variables, then, will be diameters breast high, and the dependent variables, periodic growth as determined in 5- or 10-year periods. Unless there is some special reason for determining the mean annual growth *use periodic growth on D.B.H. for all problems in many-* (or uneven-) *aged stands.*

ILLUSTRATION.—To Construct a Table of *Diameter Growth* at the Stump for Uneven-aged Stands, Based on D.B.H.

DIRECTIONS:

A. *Data Required.*—The D.B.H. and measurements of the last 10 rings at the stump, or at D.B.H.

NOTE.—The data for this problem can be obtained at D.B.H. from standing trees with the increment borer, but usually more satisfactory work can be done on felled trees in connection with a logging operation. The data supplied for this exercise were obtained in the latter manner. Use Series II. The data in this series are somewhat limited for the purpose but show admirably what a small variation enters into the final results even with limited data. Compare the results obtained under "D" of this problem as worked out by different members of the class. The problem also illustrates the need for a large number of data for absolute accuracy in all problems dealing with averages.

B. *Method.*—Averaging before plotting.

C. *Method of Procedure.*

1. Group all trees into 1-inch D.B.H. classes (*e.g.* 8-inch class 7.6–8.5, inclusive).

2. Average the periodic growth and the diameter class of all trees of each class separately. (See Problem 16 for method.)
3. Even off by a curve.
4. Construct a table showing for each D.B.H. inch class:
   (*a*) The periodic growth as read from the table.
   (*b*) The periodic annual growth.
   (*c*) The number of years required to grow 1 inch.

D. *Discussion.*

1. Solve the following problem from the above table:
   If you are cutting to a 14-inch diameter limit, in how many years will the 8-inch trees be ready to cut? Show how you derived the result.

PROBLEM 28. (Office.) THE TRANSPOSING OF A TABLE OF DIAMETER GROWTH AT THE STUMP TO GROWTH AT D.B.H.

EXPLANATION.—Since for practical purposes all measurements of trees are based on the D.B.H., outside of bark, the most valuable diameter growth tables are those which show the growth at that point. For obvious reasons it is in most cases impracticable to analyze trees at the D.B.H. The object of this exercise is to construct a table showing the rate of growth at D.B.H. outside of bark from analyses made at the stump (D.I.B.)

DIRECTIONS:

A. *Data Required.*—D.B.H., complete stump analyses, and total ages. Use the same data (Series III) used in Problem 26. The curve for average D.I.B. growth at the stump constructed in that exercise will be taken as a basis for the work.

B. *Method of Procedure.*

1. Lay off a sheet of cross-section paper as in Problem 26, and transfer the average curve from that sheet to the new sheet by plotting the values from the table made in Problem 26. Do not prick the points through the paper as this often results in inaccuracies. Label this, "Curve I, (D.I.B. Stump)."
2. On this same sheet now draw Curve II to show the ratio between D.I.B. (stump) and D.B.H. (outside of bark) as follows:
   (*a*) Let ordinates represent D.I.B. values as for Curve I. Now lay off D.B.H. values as abscissæ, the abscissæ to have the same value (in number of spaces on the paper alotted to each unit) already established for the ordinates; *i.e.*, if one large space represents 2 inches on the ordinate axis, it shall also represent 2 inches on the abscissa axis. These values may be placed directly below the age figures. *Be sure to label each set of figures.* Confusion

may often be avoided by using a distinct color for all points, curves, figures, and labels belonging together.

(*b*) Plot values of D.I.B. (ordinates) on D.B.H. (abscissa) for each tree as recorded on the Tree Measurement Blank. Select the trees, so that they will be well distributed over the various diameters. D.I.B. values can be obtained from Data Series III by doubling the last radius measurement.

(*c*) Average; draw a curve. Label this "Curve II (Ratio Curve)." It may cross Curve I.

3. These two curves now show the relationship between growth at D.I.B. (stump) and D.B.H. on age. The D.B.H. for any age may be determined as follows:

(*a*) Beginning on the abscissa axis at the desired age, trace the perpendicular at that point to the point where it crosses the D.I.B. curve (Curve I).

(*b*) From this point trace the horizontal line straight across to the Ratio Curve (Curve II). The line dropped from this point perpendicular to the abscissa axis will indicate the D.B.H. for the age started with. Show by dotted line and arrrows on the cross-section sheet how this reading is obtained.

4. It is customary to draw a third curve representing growth at D.B.H. as follows:

(*a*) On the same sheet of cross-section paper let ordinates as there laid off for Curves I and II now represent D.B.H., and ages as established for Curve I abscissæ.

(*b*) From Curves I and II read off the values of D.B.H. on age in 10-year periods, as explained in 3, (*a*) and (*b*), and plot them according to 4 (*a*).

(*c*) Even off by a curve. Call this Curve III.

5. Read off two tables.

   1. Showing the diameters (D.B.H.) at different ages in 10-year periods.
   2. Showing ages for the different diameters (D.B.H.) in even inches.

PROBLEM 29. (Office.) THE DETERMINATION OF HEIGHT GROWTH.

EXPLANATION.—The determination of height growth depends upon the principle that the number of annual rings at any point along the bole of the tree represents the number of years it took the tree to grow from that point to the tip. Thus the total age represents the number of years it took the whole tree to grow from the ground to the tip, and the number of rings at any cross-cut the number of years to grow from that point to the tip. In order to find how many years it took the tree to grow from the surface of the ground to any point intermediate between it and the tip subtract the number of annual rings that occur at the desired point from the total age.

ILLUSTRATION 1.—To construct a Table of Height Growth for *Even-aged* Stands.

DIRECTIONS:

A. *Data Required.*—Total ages and ring counts (decade measurements not needed) at various intervals along the boles of the trees, recorded with the heights above the surface of the ground at which the counts are made. Whenever height growth studies are made in connection with some study, not involving complete stem analysis, such for example, as diameter growth at the stump, it is necessary to make ring counts at various intervals along the bole for the height determinations. Usually a good height growth table can be made from a much smaller number of trees than required for diameter growth. Use data Series IV.

B. *Method of Procedure.*

1. Determine which is the independent and which the dependent variable. Ask the instructor if you are right, then lay off the cross-section paper accordingly.
2. Determine the number of years required to grow to the height of the cross-cut in question by subtracting the number of rings at the various cross-cuts from the total age.
3. Plot the values, average, and read off the proper kind of table.

NOTE in this problem the value of plotted points for interpolating values.

ILLUSTRATION II.—To Construct a Table of Height Growth for *Uneven*, or *Many-aged* Stands, Based on D.B.H.

EXPLANATION.—This exercise aims to throw the student upon his own responsibility and should be written out instead of being worked out.

DIRECTIONS.

A. *Data.*—Determine first what data (enumerating all measurements) are required.

B. *Method of Procedure.*

1. Outline the method step by step.

Suggestion.—Take into consideration the fundamental differences in the construction of growth tables in even- and in uneven-aged stands as illustrated in Problems 26 and 27, and apply to Height Growth. Determine first which is dependent and which independent variable, and whether you would use M. A. G. or Per. G. according to the procedure in many-aged stands. If you have any difficulties read again the Explanation to Problem 27.

PROBLEM 30. (Office.) THE DETERMINATION OF VOLUME GROWTH IN AN INDIVIDUAL TREE.

EXPLANATION.—Volume growth may be based on stem analysis data or on measurements taken on a large number of standing trees of different ages. In the first case the trees are analyzed in the field as in Problem 7 and the volumes of the trees at different ages are reconstructed from the analysis. In the second case average trees in even-aged stands of different ages are meas-

ured and the volumes calculated and plotted. The object of this problem is to illustrate the fundamental principles involved in all volume growth determinations based on analyses. In the different problems involved slight modifications are of course necessary in the method of collecting data and in the method of working them up into the final table. These will be emphasized in the succeeding problems. The underlying principle in the study is to reconstruct each tree analyzed on the basis of its dimensions 10, 20, etc., years ago.

ILLUSTRATION.—To Determine the Volume Growth of an Individual Tree in *Cubic Feet* and in *Board Feet*, Based *on Age*.

A. *Data Required.*—Complete stem analysis. Use tree number 116 in Data Series V.

B. *Method of Procedure.*

1. Calculate the volume in cubic feet without bark of the whole stem for each 10-year period in the life of the tree, using Smalian's formula for contents of logs, the cylinder formula for stumps, and the cone formula for tips above the last log, as follows: (Calculations for 5 to 7 ten-year periods will illustrate the problem.)

(*a*) On a sheet of note paper arrange a blank form like the following. Preserve all calculations on this form.

Cross Cut	Diameter Inside Bark, Inches	Area, Square Feet	Section	Length of Section	Volume, Cubic Feet	Volume, B.M.
1			Stump			
2			1st Log			
3			2d Log			
4			Etc.			
Etc.						
Present Time (Give Age) .... Total Volume						
1			Stump			
2			1st Log			
3			2d Log			
4			Etc.			
Etc.						
Tree 10 Years Ago (Give Age) .... Total Volume						

(*b*) Calculate the volume of the tree according to its present dimensions by calculating the volume of each section separately, and add all of them for total volume. The dimensions of the diameters may be determined from the last set of figures recorded on the analysis sheet, for each section analyzed. As they are radius measurements they should be doubled.

(*c*) In a similar manner calculate the volume of the tree by reconstructing from the analysis its dimensions at 10, 20, 30, 40 years ago and so on down to within the first 10-year period in the life of the tree. (Make only 5 to 7 calculations.) The diameters of the successive 10-year periods are again determined from the radius measurements recorded on the analysis sheet. For ten years ago, for example, the radius at each cross-section will be represented by the next to the last series of radius measurements; for twenty years ago by the third from the last, and so on. The lengths of the logs or sections are recorded on the front of the analysis sheet, including the height of the stump and the length of the tip of the present tree. The lengths of the tips of the reconstructed trees, however, must be determined by special calculations, because the tips usually end somewhere between the last cross-cut and the original tip, or between two successive cross-cuts.

Determine the lengths of the individual tips by proportion as follows:

(1) Determine the periodic annual height growth of the section above the last log in the reduced tree under consideration by dividing the length of the section by the number of years it took the tree to grow that length.

(2) Multiply the periodic annual height growth by the number of rings at the *base of the tip whose height you wish to find.* If the tip of the reduced tree happens to be in the tip of the present tree, the length of the present tip divided by the number of rings at its base will equal the periodic annual height growth. If the tip of the reconstructed tree falls within any of the sections below the present tip, the total number of rings at the top of the section subtracted from the total number of rings at the bottom of the section will equal the number of years it took the tree to grow the length of the section. Then divide the length of the section by this number of years, as just determined, to obtain the periodic annual growth (P. A. G.) in height. Multiply this by the number of rings *at the base of the tip whose height it is desired to find.*

(*d*) Determine volume of tip as usual B.A.$\times \frac{1}{3}$H.

(*e*) Enter the volumes of the separate sections of each reconstructed

tree in the proper place on the blank form and add for total volume.

2. Now determine the rate of volume growth in *board feet* in a similar manner to that just described, except as follows:
   (*a*) Use only the merchantable portion of the stem, assuming everything merchantable above the stump down to 6 inches D.I.B. at the top of the log. Tips and stumps, of course, must be omitted, also logs whose top diameters are less than 6 inches.
   (*b*) Use the International Log Rule as worked out in Problem 9 or any other rule giving values down to 6 inch top diameters, for determining the board foot values.
   (*c*) Record the values in their proper places in the blank forms, and total.
   (*d*) Make a final table showing only the volume in cubic feet and in board feet in 10-year age periods.

C. *Discussion.*

1. What would be some of the practical applications of such a table.

PROBLEM 31. (Office.) THE DETERMINATION OF VOLUME GROWTH BY GRAVES' MODIFICATION OF MLODJIANSKI'S METHOD.

EXPLANATION.—A table showing growth based on age might be constructed from analysis data by first calculating the volume growth of each individual tree as was done in Problem 30, and averaging the results to determine the average rate of growth. The student will realize fully from the foregoing exercise without further emphasis the tremendous amount of work necessary if a number of trees sufficient to give good average results are used. The object of the method described in this problem is to reduce the number of calculations to a minimum. Mlodjianski's principle is first to determine by means of separate curves the average dimensions of the trees at different ages, and from them to calculate the volume growth rather than to calculate the volumes first and then determine the averages. Graves' modification consists in arranging the averaged curves in graphic form on one sheet of cross-section paper in such a manner that the dimensions of a tree of any age may be determined at a glance. The principle underlying the method as proposed by Graves is to have the curves for the diameter growth at each cross-cut placed on the co-ordinate paper with reference to the total age of the tree instead of the number of rings at the cross-cut in question. Remember, that the age at the stump does not represent the total age of the tree, because no rings are represented in the cut surface of the stump for those years during which the tree grew to stump height. The problem, then, is to show in the diameter growth curve for the stump how many years in the whole life of the tree it took to produce a stump of a certain diameter and not how many years after the tree had grown to stump height. In this problem the curve for each cross-cut

will then begin to the right of the original zero, at the intersection of the co-ordinate axes, as many units (years) as it took the tree to grow from the ground to the respective cross-cuts.

DIRECTIONS:

A. *Data Required.*—Complete stem analysis of trees cut into logs of equal length where possible. Unless other data are available the three selected trees of Data Series V. will suffice for purposes of illustration.

B. *Method.*—Plotting the values before averaging.

C. *Method of Procedure.*

1. Construct a height growth table showing the average time required for the trees to grow from the ground to the various cross-cuts.
2. Determine the average stump heights.
3. Draw a diameter growth curve for the stump just as was done in Problem 26. Label it *Stump Curve* and indicate the average stump height on it.
4. In a similar manner, and with the same values for abscissæ and ordinates, draw a separate diameter growth curve for each of the succeeding cross-cuts, *i.e.*, if the average stump height is 2 feet and the logs are cut in 16-foot lengths, the second curve will represent the growth at a point 18 feet above the ground, the third at a point 34 feet above the ground and so on. Label each with its average distance above ground.
5. Now transfer all the curves to one sheet in such a manner that the growth at the respective cross-cuts will be shown on the basis of *total age; i.e.*, let each curve begin as many years to the right of the intersection of the two axes as it took the tree to grow to the height of the cross-cut in question. Determine this point in each case from the height growth table. Do not transfer the curves by means of pin pricks, but plot the average values.
6. Determine the average height of the oldest trees from the height growth curve. Indicate this average by drawing a short perpendicular through the age axis at the proper point, and label it "Average Total Age," below the axis. Just above the axis at this point write in the average total height and label.
7. These curves represent the diameter growth at their respective distances above ground, on the basis of total age (the age at the ground) and not on the basis of the age at the respective cross-cuts. The points on the age axis together with the average total age, the average total height and the points where the curves at different heights cross the axis represent height growth. Hence this series of curves will give for any age the dimensions of the trees, D.I.B. at various points along the bole, and the total heights. For points at distances above the ground that are intermediate between the

curves constructed interpolate. A D.B.H. growth curve may also be added by the method of Problem 28.

8. Determine the dimensions of the trees—D.I.B. at the stump, and at the end of each section (log) and the total height—for even 10-year periods beginning with 10 years, and proceeding through to the time the trees were cut. Arrange in table form.
9. From the preceding table construct a Volume Growth Table showing (*a*) the growth of the entire stem in cubic feet, and (*b*) the growth in board feet of the merchantable stem, for each 10-year period. Consider 6 inches D.I.B. for the merchantable top diameter limit. Use the International Log Rule, or any other with values down to 6 inches top diameter for determination of board foot contents.

PROBLEM 32. (Office.) The Determination of Maximum Growth

Explanation.—The object of determining maximum growth is chiefly for the purpose of finding out how fast all the trees in an unthinned stand would grow assuming that each could be made to grow as fast as the most rapidly growing trees, providing they were given the proper treatment. The method of procedure as given in the accompanying illustration would be applicable to *any* of the various kinds of growth studied and may be applied to any of the succeeding growth exercises. The data for this exercise may be obtained either by analysis of a large number of trees of different sizes, or by selecting only the maximum trees for analysis. In the latter case the maximum growth would be determined directly from these analyses by the same method of procedure as described in Problem 26, if collected by first method referred to, as described in the illustration below.

Illustration.—To Determine the Maximum Diameter Growth at the Stump in Even-aged Stands by Constructing a Maximum Diameter Growth Curve.

Directions:

A. *Data Required.*—Stump analyses and total ages of selected trees of different sizes. As the values are plotted exactly as in Problem 26, the same sheet of cross-section paper with its plotted points may be used.

B. *Method of Procedure.*

1. Using the same sheet of cross-section paper with its plotted points that was used in Problem 26, draw a smooth curve as an upper boundary to the *main* body of the plotted points, being careful to exclude all points that indicate abnormally high values.
2. Read off a table showing the diameters of the maximum trees for each even 10 years.

SECTION IX. SAMPLE PLOT STUDIES

Explanation.—Sample plot studies are useful for the determination of the contents of stands, for solving certain problems in growth, and as a preliminary step in the construction of yield tables. In order that all of these different problems may be worked out as laboratory exercises from the same felled sample trees, and that unnecessary duplication of work may be avoided, this section is placed immediately following the section on Growth Studies.

The underlying principle in all sample plot studies is to obtain the desired information by the measurement of a few carefully selected average trees in sample plots representing average conditions, and then to apply the combined average results as obtained from the sample plots to an entire tract. It should not be necessary to emphasize here that the greater the number of plots used the greater will be the accuracy of the results.

For a rough check in practical work, or where sample trees can not be felled a standard volume table may be used to determine the volumes of the sample trees. Do not do this where great accuracy is required.

PROBLEM 33. (Field.) The Determination of the *Contents* of a Stand by Means of Felled Sample Trees.

Explanation.—The accompanying illustrations include three distinct methods. With them as a foundation the student should have no difficulty in understanding the underlying principles of any method. It is suggested that this exercise be carried out in young, nearly even-aged stands. They will serve the purpose of illustration fully as well as older stands, and, further, will result in a considerable saving of time and unnecessary manual labor. Each student should have a complete set of all the data and calculations obtained by the other members of his party. These should be collected from the other members immediately after each problem has been completed. In each of the accompanying illustrations arrange the data and the results in logical order so that each step will be indicated in the proper place.

Illustration I.—The Mean Sample Tree Method.

Principle.—The principle of this method is to base the contents of the sample plot on the contents of one or more trees, each of which represents the average of all the trees within the sample area.

DIRECTIONS:

A. *Parties.*—3 men. The organization of the work for each man is left to the "Chief of Party" designated by the instructor. He will be marked on the efficiency with which his party carries out the work. Remember that every man should be kept busy.

B. *Equipment Required.*

1 100-foot steel tape.
1 surveyor's compass, or 1 angle mirror.
2 pairs of tree calipers.
1 cross-cut saw.
1 hand axe.
2 bark scratchers (white carpenter's chalk often answers the purpose even better).
3 field notebooks (one per man), with blank Forms 1, 2 A, and 3 A, and cross-section paper.

C. *Method of Procedure.*

1. Determine the area of the tract. In order to save time assume an arbitrary area of 40 acres.
2. Make a careful examination of the entire tract for the purpose of selecting a plot that will represent average conditions.
3. Carefully lay off a sample plot ($\frac{1}{4}$ to $\frac{1}{16}$ acre will do to illustrate the problem). Mark the boundaries carefully.
4. Caliper all the trees in the sample area at D.B.H. to the nearest inch, down to a minimum diameter of 2 inches. Mark each tree calipered, to avoid repetition. For convenience in recording the measurements use a form similar to that used when cruising on the basis of diameters only. (Form 3 A.)
5. Arrange all data, including the calculated values, in a convenient tabular form.
6. Determine the diameter of the average tree by the formula:

$$b=\frac{b_1n_1+b_2n_2+b_3n_3+\text{etc.}}{N},$$

in which b = the average basal area of all trees on the plot;
b_1, b_1, etc. = basal areas of the different diameters;
n_1, n_2, etc. = number of trees of each diameter;
N = total number of trees on the plot.

Use table of basal areas for getting the diameter values of b.

7. Cut three trees whose diameters fall within 0.5 of an inch of the diameter of the average tree. Be careful to select trees of average height and crown development. *Number the stump of each tree to correspond with the number of the record sheet so that both may be used for future problems.* Record measurements on Form 2 A.

8. Determine the volume of each in cubic feet by Smalian's method, using 10-foot sections.
9. In order to correct any error resulting from a difference in the diameters of the sample trees and that of the average tree as calculated determine the contents of the average plot by the formula:

$$V=\frac{v\times B}{b},$$

in which V = the volume of the average acre;
v = average volume of test trees;
B = total basal area of the plot;
b = average basal area of the test trees.

Reduce to acre terms.

10. Determine the contents of the entire stand. (40 acres assumed.)

ILLUSTRATION II.—The Arbitrary Group Method.

Principle.—The principle of the method is to group all the trees measured on the plot into arbitrary D.B.H. classes. Each group is then treated in exactly the same manner as were all the trees in the Mean Sample Tree Method. The chief difference between this and all other methods in which the trees are grouped is in the manner of grouping and the number of test trees to be cut.

DIRECTIONS:

A. *Parties and Equipment as in Illustration I.*

B. *Method of Procedure.*

1. Use the same area for the tract, the same plot and the same diameter measurements of the standing trees as in Illustration I.

NOTE.—The same plot is here suggested for each illustration given in order to give the student a thorough basis for comparing the different methods. Sometimes the plots can be located in timber which will be cut before the completion of the course in mensuration. In that case all the trees can be carefully measured, and the contents can be computed accurately from the felled trees and then compared with the results obtained by the different sample plot methods.

2. Group the diameter measurements into three or four groups, so that each group or diameter class does not, so far as possible, vary by more than 4 inches.
3. Proceed with each group (diameter class) just exactly as was done for all the trees in Illustration I. Record sample tree measurements on Form 2 A.
4. Arrange all data in tabular form similar to that used in Illustration I.
5. From these measurements now determine the cubic foot contents of the 40-acre tract.

ILLUSTRATION III.—The Volume Curve Method.

Principle.—This method differs from all others in that no determination of average trees is necessary. The underlying principle depends upon the construction of a volume curve based on D.B.H. made from a few trees selected so that the small, the medium and the large sized trees are represented.

DIRECTIONS:

A. *Parties and Equipment as in Illustrations I and II.*

B. *Method of Procedure.*

1. Use the same area and the same sample plot with its tree measurements as in Illustrations I and II.
2. Select 6 sample trees without reference to any particular diameter but apportioning them so that the large and the small trees will be represented, and so that in a measure the diameters for which the largest number of trees have been recorded will be given the largest number of sample trees.
3. Fell the sample trees, and determine their total cubic foot contents, without bark, by means of ten-foot sections.
4. On a sheet of cross-section paper now plot the volumes of the sample trees on their diameters (D.B.H.). Draw a smooth curve, and read off a table of volumes for diameters in whole inches.
5. Apply the volume table to the measurements of the trees on the plot to determine the contents of the whole plot and from the latter the contents of the tract.

C. *Discussion.*

1. Comment on the three methods giving your views on the advantages and disadvantages of each with reasons.
2. Outline methods of procedure for the *Urich* and for the *Draudt* methods.
3. What per cent of a tract should be measured to insure a good estimate?

PROBLEM 34. (Field.) THE DETERMINATION OF THE *Rate of Growth* IN EVEN-AGED STANDS BY THE ANALYSIS OF *Felled Sample Trees.*

EXPLANATION.—This exercise endeavors to illustrate in a practical manner the chief problems in growth in even-aged stands that may be solved by means of felled sample trees. As the details of the method of procedure have been illustrated in connection with previous problems the student should be able to carry out the work of the accompanying illustration from very general directions, and the directions in the Method of Procedure have been so made. The scheme will serve, in addition to illustrating the problems

involved, as a thorough review of the procedure in growth studies. References are made to previous problems, but the student will gain the greatest benefit from this exercise if he does not make use of them until he has found by actual trial that he cannot work out the problems without using the references.

Directions:

A. *Parties.*—3 men.

B. *Equipment.*—After reading over the exercise the student should determine what equipment is required. (See Problems 6 and 7.) Ask the instructor if you are right before starting for the field. The chief of party will be held responsible.

C. *Method of Procedure.*

1. Use the original data and the felled sample trees obtained in the Mean Sample Tree method of Problem 33.
2. Make a complete stem analysis of the felled sample trees. (Use regular analysis sheet for recording measurements. Forms 2, A and B.)
3. Work out the following problems. Arrange all work in logical order:
   (*a*) Construct a table of diameter growth at the stump. (See Problem 26.)
   (*b*) Construct a height growth table on total age. (See Problem 29.)
   (*c*) Construct a cubic foot volume growth table in 10-year periods. Use Graves' Modification of Mlodjianski's Method. (See Problem 31.)
   (*d*) From (*c*) determine the volume growth per acre in cubic feet.

D. *Discussion.*

1. Under what conditions would the method of this problem give satisfactory results concerning growth? When applied to mature stands, of which trees *only* does it show the growth throughout the entire life of the stand?
2. Which of the following methods would give the most satisfactory results for a growth study: Mean Sample Tree, Arbitrary Group, Draudt, or Urich? Why?
3. How many plots would be considered sufficient for a reliable study in any one type? How large would you say, judging from your studies involving the use of plots, should plots ordinarily be to insure getting average conditions?
4. How would you modify the method of procedure if this problem were to be carried out in a mixed stand?

PROBLEM 35. (Field and Office.) THE DETERMINATION OF GROWTH IN EVEN-AGED STANDS BY THE MEASUREMENT OF *Standing Trees*.

EXPLANATION.—In the method of the last problem (No. 33) it will be remembered that good results can be obtained only when worked up in mature stands, and that the results will then show the rate of growth of only those trees which reach maturity. The method of this exercise will show the average rate of growth of all trees throughout the life of the stand. As it is only a comparatively small step from this exercise to the fundamental problems involved in the construction of yield tables showing the average total stand *per acre* at any period in the life of the stand, the exercise is here outlined so as to cover the necessary work for these, namely to select the plots located in different site qualities and to calculate values in terms per acre.

This problem requires second growth even-aged stands of different ages. In order that a sufficient number of plots may be measured to insure enough to illustrate the exercise the instructor should at the outset arrange the work of each party in such manner that as large a range of ages will be obtained as the conditions of the locality and the size of the class will warrant. The students should now be able to carry out this work without much supervision by the instructor, and the different parties can be scattered over a wide territory.

DIRECTIONS:

Part I.—Field Work

A. *Parties.*—3 men in each.

B. *Equipment.*—Determine what instruments and other equipment are necessary for each party, and have the instructor check your list before starting for the field. The chief of party will be held responsible.

C. *Method of Procedure.*

1. Carefully lay off sample plots of $\frac{1}{16}$–$\frac{1}{2}$ acre in stands of different ages. If good average conditions cannot be found in $\frac{1}{2}$-acre plots, larger plots should be used. In order that these same data may be used in connection with the work in yield tables, some effort should be made to secure them from different site qualities.
2. Measure all trees at D.B.H. and record as in cruising.
3. Number and describe the locality of each plot on the tally sheet. Use U. S. land subdivisions where possible.
4. Determine the following information in the field with reference to each plot, using the Mean Sample Tree Method for determining any points requiring felled sample trees.
    (*a*) The number of trees per acre.
    (*b*) The diameter of the average tree.
    (*c*) The volume of the average tree.
    (*d*) The average height. (Measure 6 to 10 representative trees of the average diameter with the hypsometer and average.)
    (*e*) The average age.

Part II.—Office Work

NOTE.—In order that enough data for the construction of a table may be at hand the field work of the entire class should be collected for the use of each student. (For schools so situated that it is impracticable to collect appropriate data, Data Series VI has been included in the Appendix.)

A. Construct a table giving the following information in 10-year periods:

(*a*) The average number of trees per acre;
(*b*) The diameter of the average tree;
(*c*) The average diameter;
(*d*) The average total basal area in acre terms;
(*e*) The average height;
(*f*) The average volume in cubic feet in acre terms.

NOTE.—All average values should be evened off by curves.

B. Arrange all data, curves and other work in logical order.

C. *Discussion.*

1. Outline the measurements and office work required as if the object were to show only the growth at D.B.H. in 10-year periods.
2. Compare this method with that of Problem 33 with reference to the conditions under which each would be applicable.
3. Could this method be modified for the determination of growth in uneven-aged stands? If so, show how you would modify it. If not, why not? Consider in your reply the difference in the character of the stands, and in the silvicultural conditions of growth, and the method of studying growth in uneven-aged stands. (See Problem 27.)
4. Would the method be applicable to mixed stands? Show how, or, if not applicable, why not?
5. Which would you consider the more accurate for the determination of the average age, the average age of the sample trees or the average age of the dominant trees? Why?

SECTION X.—STUDIES IN GROWTH PER CENT

EXPLANATION.—Growth per cent is chiefly useful in the prediction of volume growth for short periods, and is a method used in connection with the preparation of working plans for even-aged stands, and in the determination of the final volume to be cut. Equipment required for field work is not listed with the exercises of this section. The chief of party will in each case be held responsible for checking out the necessary equipment.

PROBLEM 36. (Field.) THE DETERMINATION OF FUTURE VOLUME BY MEANS OF GROWTH PER CENT CALCULATED *From Felled Sample Trees.*

EXPLANATION.—This exercise aims to illustrate three of the fundamental methods. For purposes of comparison it is suggested that all of them be carried out on the same sample plot.

ILLUSTRATION.—To Determine What the Volume in Cubic Feet of a 40-acre Tract (area assumed) Will Be 10 Years Hence.

Method 1.—By comparing the Average Volume Growth for the past ten years as interest to the Volume 10 years ago as Principle.

DIRECTIONS:

A. *Formula.*

$$\frac{V-v}{n} : v = p : 100,$$

$$p = \frac{V-v}{vn} \times 100$$

where p = growth per cent;
V = present volume;
v = volume 10 years ago;
n = 10 years.

B. *Parties.*—3 men in each.

C. *Method of Procedure.*

1. Select and carefully lay out an average plot of $\frac{1}{4}$ acre.
2. Proceeding as in the Mean Sample Tree Method, determine the volume of the plot and the average tree.
3. Select and fell three average trees for measurement.

4. Determine the present full-stem volume (inside bark) and the volume 10 years ago, of each by means of 10-foot sections, and average.
5. Determine the growth per cent by substituting in the formula the values obtained in 4.
6. Calculate from the growth per cent what the volume of the tract (assume 40 acres) will be 10 years hence.

Method 2.—By Comparing the Average Volume Growth for the past 10 years as interest to the Average of the Present Volume and the Volume 10 years ago as Principle.

DIRECTIONS:

A. *Formula.*

$$\frac{V-v}{n} : \frac{V+v}{2} = p : 100,$$

$$p = \frac{V-v}{V+v} \times \frac{200}{n}.$$

The symbols are the same as in Method 1. This is considered the most satisfactory formula for all general purposes.

B. *Method of Procedure.*

1. Proceed as in Method 1 using the same felled sample trees.

Method 3.—By Comparing the Average Volume Growth for the past 10 years as interest to the Volume one year ago as principle.

DIRECTIONS:

A. *Formula.*

$$\frac{V-v}{n} : \left(V - \frac{V-v}{n}\right) = p : 100,$$

$$p = \frac{V-v}{V(n-1)+v} \times 100.$$

B. *Method of Procedure.*—Proceed as in 1 and 2, using the same felled sample trees.

C. *Discussion.*

1. Present the mathematical derivation of each of the formulæ used.
2. Arrange the results of the three methods in a comparative series. Give your opinion of their relative values.
3. Which of the above methods are applicable to mature, and which to young stands?
4. Outline a method of procedure for use in mixed stands.
5. Are any of the above methods applicable to uneven-aged stands? If not, why not?

PROBLEM 37. (Field.) THE DETERMINATION OF FUTURE VOLUME IN *Immature Even-aged* STANDS BY MEANS OF GROWTH PER CENT CALCULATED FROM *Standing Trees.*

ILLUSTRATION.—To determine what the volume of a stand will be ten years hence by means of Pressler's formula for immature trees.

EXPLANATION.—In this formula Pressler starts with the factors of volume, $V=\frac{\pi D^2HF}{4}$ as a basis and eliminates F, the form factor, by assuming that trees will not materially change in form in ten years, and by further assuming that the change in height is proportional to the change in diameter he eliminates the height factor, H, by finding its value in terms of the diameter thus evolving the formula as given below for immature trees. For mature trees he evolves the formula,

$$\frac{D^2-d^2}{D^2+d^2}\times\frac{200}{n},$$

assuming that there is practically no change in either height or form factor.

DIRECTIONS:

A. *Formula.*

$$p=\frac{D^3-d^3}{D^3+d^3}\times\frac{200}{n},$$

where p = growth per cent;
D = D.B.H. of present tree;
d = D.B.H. of tree 10 years ago;
n = 10 years.

B. *Method of Procedure.*

1. Use the same plot used in the preceding problem.
2. Find 3 standing trees of the requisite diameter, either on this plot or adjacent to it.
3. With calipers find the average present diameter of each tree by means of two measurements at right angles to each other.
4. With the increment borer, by means of two borings at right angles to each other on each tree, find the average diameter ten years ago.
5. Substitute the averaged values for D and d of the three trees in the formula for growth per cent.
6. Calculate what the volume of the tract (assume 40 acres) will be 10 years hence.

C. *References.*—Numbers 66 and 82.

D. *Discussion.*

1. Show by means of the mathematical derivation of Pressler's formula how he justifies the use of this formula for immature stands.

2. Compare the results of this exercise with those derived by the three different methods of the previous exercise, and comment on the efficiency of Pressler's formula.
3. What is Pressler's formula for mature or nearly mature stands?

PROBLEM 38. (Field.) THE PREDICTION OF FUTURE VOLUME IN *Mature Stands* BY MEANS OF GROWTH PER CENT.

EXPLANATION.—Schneider's formula is applicable only to mature trees. It has been found to be one of the most reliable and easily used formulæ.

ILLUSTRATION.—To determine what the volume of a stand will be 10 years hence by means of Schneider's formula.

EXPLANATION.—Schneider's formula uses the periodic annual growth as determined by the last inch radius as interest and the average of the volume one year ago and one year hence as principle. He assumes there will be no change in height or form factor.

DIRECTIONS:

A. *Formula.*

$$p=\frac{400}{nD},$$

where p = growth per cent;
D = present D.B.H. (outside bark);
n = number of rings *in the last inch radius.*

B. *Method of Procedure.*

1. Lay off a sample area of $\frac{1}{2}$ acre in an old stand of timber. (If the trees are very large or scattered use 1 acre.)
2. Determine the average tree by means of the Mean Sample Tree Method.
3. Make the necessary measurements on three trees. Average and apply in the formula for growth per cent.
4. By means of the growth per cent calculate the volume of the tract (40 acres) 10 years hence.

C. *Discussion.*

1. Show step by step how your results were derived.
2. Show by means of the mathematical derivation of Schneider's formula why it is not applicable to immature trees.

SECTION XI.—YIELD TABLE STUDIES

Explanation.—Yield tables are tabular statements which show the average stand of timber per acre. As in volume and growth studies separate tables are made for stands growing under different conditions or having distinct characters. They are made both for even-aged stands and for uneven-aged stands. Two forms are recognized for the even-aged stands: 1. The Normal Yield Table, showing the stand per acre of normal or fully stocked stands, and 2. The Empirical Yield Table, showing the average stand in any locality irrespective of stocking. By a fully stocked stand is meant one with the average maximum yield obtainable under the existing conditions.

The construction of yield tables for even-aged stands does not present any great difficulties. Yield tables for many-aged stands, however, offer a number of serious difficulties. Up to the present time there has been no general method devised for constructing these that is wholly satisfactory. For this reason problems for many-aged stands have been omitted, but a list of references to the various methods is included at the end of this section. In dealing with yield tables the student should remember that he is dealing with values per acre.

PROBLEM 39. (Office.) The Construction of Yield Tables for *Even-aged Stands*.

Explanation.—In the foregoing problems the student has had practice in nearly all the steps necessary for the construction of the different kinds of yield tables for even-aged stands. The Method of Procedure in Problem 35 covers practically all of the points necessary for the collection of field data. In fact in that exercise the student has virtually constructed an *Empirical* Yield Table. All that is now necessary to further illustrate the work is to take up the special problems that arise in connection with the construction of *Normal* Yield Tables.

Illustration.—To Construct a *Normal* Yield Table for *Unthinned Pure* Stands.

Directions:

A. *Data Required.*—The measurement of permanent sample plots would of course give the best results. However, when time is an important consideration these are out of the question, since it would take years to collect the necessary data by this means. To overcome the difficulty

of the time element we measure a large number of sample plots in even-aged stands from youth to maturity, in different site qualities, and as fully stocked as possible. Use data collected (or used) in Problem 35.

B. *Method of Procedure.*

1. Group the plots into 3 site qualities.

Method I.—Bauer's Method of Bands.

(*a*) Plot the volumes (cubic feet) in acre terms on age. In each case be sure to place the number of the plot with the plotted points. (The data of Series IV are arranged according to site qualities.)

(*b*) Enclose the plotted points between 2 regular curved lines. Divide the space between them into 3 equal bands by first indicating the proportional distances on the vertical lines from the abscissa axis at each 10- or 20-year point and then join the indicating marks by regular curves.

(*c*) Include all plots in the highest band in Site Quality I, those in the middle in Site Quality II, and those in the lowest in Site Quality III.

Method II.—The Site Factor Method.

(*a*) Determine the site factor for each plot by means of the following formula:

$$F = \frac{h \times B}{a},$$

in which F = the site factor;
h = the height of the average tree, which is to be determined from a height-diameter curve. The height of the average tree is to be taken as the height shown for the tree of average diameter;
B = basal area in square feet per acre;
a = the average age of the stand.

(*b*) Divide all the site factors into 3 groups of equal numerical range in volume. All plots whose site factor falls within the range of the highest group will belong to Site Quality I, those of the middle group into Quality II, and those of the lowest into Quality III.

(*c*) Determine the basal areas and plot.

(*d*) Arrange the results obtained by the two methods in a comparative table.

2. Determine the *normality of stocking* by Bauer's Method as follows:

(*a*) Draw an average curve and exclude from the investigation all plots whose volumes vary by more than 7.5 per cent from the average. These are either abnormally stocked or understocked.

(b) Normality can also be determined, and that often more rapidly by comparing the basal areas of all plots of the same age and site quality without curves as follows:

1. Determine the average total basal areas of plots of same average age.
2. Plots whose areas do not fall within 7.5 per cent of this average are discarded.

3. Average the plotted points of each site quality separately, even off with a regular curve, read off the average volume per acre in 10-year periods, and arrange in table form.
4. In addition to the yield the Normal Yield Table should also include the following information for each 10-year age period:
   (a) The average height;
   (b) The average diameter (D.B.H.);
   (c) The number of trees per acre;
   (d) The total basal area in acre terms;
   (e) Sometimes also the form factor and the growth per cent.

   All of the above are determined just as they were in Problem 34, except that stands not normally stocked are not included and all calculations are made separately for each site quality.

C. *References.*—Numbers 71, 74 and 86.

D. *Discussion.*

1. Name in the order of procedure all the important steps necessary in the collection of data for the construction of a Normal Yield table.
2. What other factors beside volume may be used to determine normality of stocking? Under what circumstance would it be more advantageous to use a different factor?
3. What factor beside volume may be used to determine site quality by Bauer's Method of Bands?
4. What would be the chief difference in the collection of data for Normal and Empirical Yield Tables?
5. Outline briefly the main steps in the method of procedure for collecting data for a yield table thinned for the first time in late life.
6. Outline briefly a method of procedure for a yield table for mixed stands, assuming that we have an even-aged stand of Douglas Fir with an under-story of hemlock.

PROBLEM 40. (Field.) METHOD OF USING YIELD TABLES IN THE FIELD.

EXPLANATION.—Yield tables are used to show the future returns from plantations and immature stands, for estimating, for the determination of site quality, and, with reference to working plans, the growing stock, the normal yield and the rotation. That the students may work this exercise out prac-

tically, it will be necessary to place in their hands a yield table applicable to the section of the country in which they are working. A yield table for Second Growth Douglas Fir will be found in the Appendix. Others can sometimes be obtained in Forest Service publications dealing with the particular region in question, or they may in some cases be obtainable from the Forester at Washington, D. C. The illustrations given below are outlined with reference to Normal Yield Tables. If these are not available Empirical Tables will do, but in that case provision should be made in the directions for the discrepancy that will arise in connection with the question of normality of stocking.

Choose for the purpose of illustrating this exercise young, even-aged stands, preferably under 50 years old, and as fully stocked as possible.

Illustration I.—To Estimate the Contents of a Stand.

A. *Parties.*—3 men in each.

B. *Equipment.*—To be determined by chief of party.

C. *Method of Procedure.*—Lay out a representative plot of ½ acre in the tract to which the table is to be applied and by means of the Mean Sample Tree Method determine the following:

1. The *average age* of the stand as the age index. When the age is not an even multiple of 10, all calculations will need to be reduced by proportion to the nearest 10-year period in the table.
2. The *average height* * of the stand as an index to the site quality.
3. The *total basal area* (in acre terms) as in index to the normality of stocking. This should be stated in terms of the per cent of the total basal area indicated in the table.
4. The *yield.* Reduce the yield indicated in the table by the per cent of stocking.

Illustration II.—To determine what the Volume of the Stand will be when it is 100 years old.

A. *Method of Procedure.*—With the information obtained in Illustration I it is now only necessary to refer to the table to obtain the future yield. The yield indicated for the 100-year-old stand should be reduced by the per cent of stocking.

B. *References.*—Number 68.

C. *Discussion.*—In the two illustrations given above no use was made of: (*a*) The number of trees per acre; (*b*) The average diameter at the different ages; (*c*) The form factor. What is the object of including these in a yield table?

Uneven-aged Stands

The following references may be helpful in understanding the question of yield tables for uneven-aged stands: Numbers 69, 70, 75, 77, 78 and 79.

* If the site factor has been established for the region it may be used.

APPENDIX

A DIAGRAM FOR THE CORRELATION OF METHODS IN FOREST MENSURATION

(EXPLANATION)

The accompanying diagram will show with reference to the character of the stand (forest description) the data required and the method of computation for practically all problems in growth studies. It also serves to correlate and illustrate the relationship between the various different individual problems.

To use the diagram begin at the center and follow an imaginary radius line straight from the center through the sections that will indicate the character and previous treatment of the stand (forest description) to *Data Required;* read the data indicated opposite diameter, height, volume or yield as required; continue the same radius into the circle marked *Computations* and read as indicated for the type of study.

Example: Desired a volume growth table for Even-aged, Pure Stands, Regularly Thinned:

Begin at center—Follow a radius that cuts the even-aged sector, the pure-stand sector, and the regularly-thinned sector to "data required." In this circle we have indicated opposite "Vol." the data required for this study. Continue this same radius to the circle marked "Computations," the methods of working up the data, as indicated opposite "Vol."

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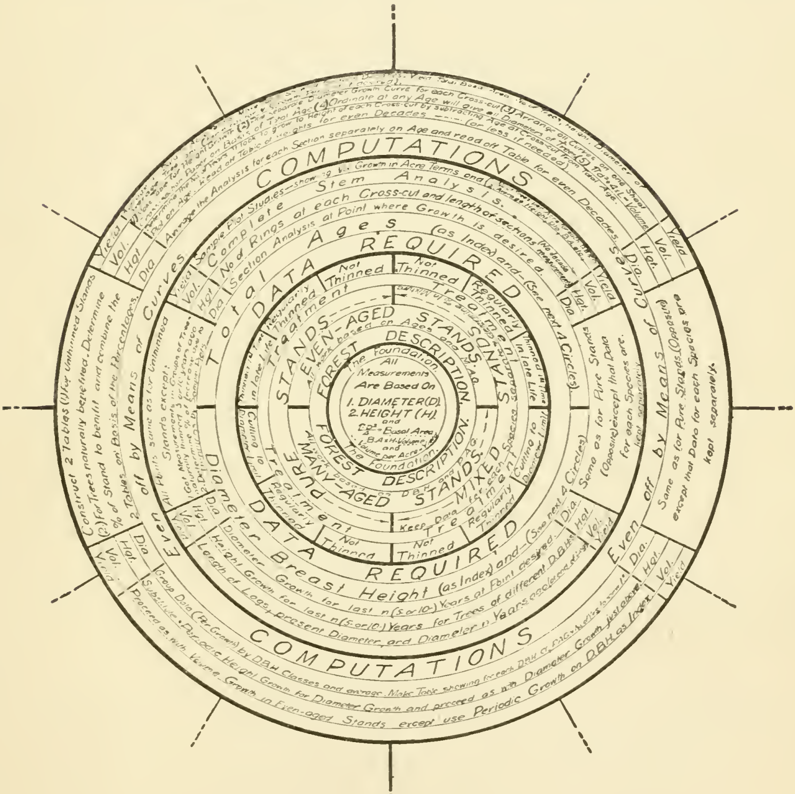
DIAGRAM—CORRELATION OF METHODS IN GROWTH STUDIES



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UNITS OF MEASUREMENT

Used in Land Surveying and Forest Mensuration

1 Mile

5280 feet
80 chains (66 feet each)
320 rods ($16\frac{1}{2}$ feet each)
16 tallies (5 chains each)
1000 standard double paces (5.28 feet)
2000 standard single paces (2.64 feet)

1 Acre

43,560 square feet
10 square chains
160 square rods
2 chain strip, 1 tally in length

1 Section

640 acres
16 "forties" (square forty acre tracts)
1 mile square

DIMENSIONS OF FRACTIONAL ACRE TRACT

Size of Fractional Tract (Acres)	Area of Fractional Tract (Square Feet)	Length of Side if Square (Feet)	Length of Radius if Circular (Feet)
1	43,560	208.7	117.8
$\frac{1}{2}$	21,780	147.6	83.3
$\frac{1}{4}$	10,890	104.4	58.9
$\frac{1}{8}$	5,445	73.1	41.6
$\frac{1}{16}$	2,722.5	52.2	29.4

MENSURATION FORMS

Form 1

FORM 2A

Series............Species..

Locality................S............T............R........., ...M

Regular Volume Measurements							As Used by Logger				
Section	Age, Years	Length, Feet	D.I.B., Inches	Bark Width, Inches	D.O.B., Inches	Volume	Length, Feet	D.I.B., Inches	Volume, B.M.		
1 St.											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

Tree No... ... SUMMARY Plot No........

D.B.H.	Total Age	Total Height	Mer. Length	No. of Logs	Volume, Cubic Feet	Volume, B.M.	Used Length	Clear Length	Volume, B.M.		

Name Date

FORM 2B

Cross-section	Distance on average radius from heart to each 10th ring—inches. (Count in, measure out)																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 St.																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			
15																			

Cross-section	Distance on average radius from heart to each 10th ring—inches. (Count in, measure out)																		
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1 St.																			
2																			
3																			
4																			

FORM 3A

Form 494—D 6b
(Revised, 1917)

UNITED STATES DEPARTMENT OF AGRICULTURE

FOREST SERVICE

D-6 DOUGLAS FIR REGION

TIMBER SURVEY TALLY SHEET

Check 40 to show course by

4	3	2	1
5	6	7	8
12	11	10	9
13	14	15	16

T...... N S

R...... E W

Sec.......

40 No......

Sheet......

Ht. Class............ Site...............

Compassman..........................

Estimator..........................

Date..............................19...

Est. { ....Applies to { .... / .... / Tot........Acres / Tot......A.

D.B.H.	D.F.							
10–14								
16								
18								
20								
22								
24								
26								
28								
30								
32								
34								
36								
38								
40								
42								
44								
46								
48								
50								
52								
Gross vol. on strip								
Cull % B D								
Vol. strip Net								
Vol. on 40 Net								

D.B.H.	D.F.	
54		
56		
58		
60		
62		
64		
66		
68		
70		
72		
74		
76		
78		
80		
Sound, D.F.		
Def., D.F.		
Total		

Snags over 30 ft. tall
D.B.H.
20–36
37–48
49 up
No. per A.
Average stand per A.

FORM 3B

Forest Types: ....

Age Classes: ....

Condition of Timber:

Thrifty..................%.

Mature..................%.

Decadent.................%.

Fire killed...............%; damaged.................%.

Insect killed.............%; damaged.................%.

Other killed.............%; damaged.................%.

Name of disease..

Species affected..

Quality of Timber:

[Give by log grade; percentage of tall, medium, or short clear boles; or number of clear logs of stated minimum length and diameter.]

Logging factors:

Undergrowth—Light, medium, dense.

Wind fall—Light, medium, dense.

Boulders and broken rock—Numerous, occasional, absent.

Other factors..

Reproduction:	*Species.*	*Per cent.*
No reproduction..........................	....	....
Ground ⅓ stocked........................	....	....
Ground ⅔ stocked........................	....	....
Ground fully stocked.....................	....	....

Additional Notes:

FORM 4A

	Douglas Fir						Western Red Cedar											
D.B.H.	to 75	76 to 105	106 to 135	136 to 165	166 to 195,	etc.	to 75	76 to 105	106 to 135	136 to 165	166 to 195,	etc.	to 75	76 to 105	106 to 135	136 to 165	166 to 195,	etc.
14																		
16																		
18																		
20																		
22																		
24																		
26																		
28																		
30																		
32																		
34																		
36																		
38																		
40																		
42																		
44																		
46																		
48																		
50																		
52																		
54																		
56																		
58																		
60																		
62																		
64																		
66																		
68																		
70																		
72																		
74																		

FORM 4B

Acre No...Sec.....................T.....................R..........

Course....................Offset....................Ch's....................from..........

Compassman..Date..................................

Cruiser..

Per cent of cruise..

Width of strip...

FOREST DESCRIPTION

Type

Slope

Aspect

Rock

Soil

Humus

Ground Cover

Undergrowth

Reproduction

Density

Quality of Locality

Condition of Stand

Age of Stand

Remarks

FORM 5

Locality .... Brand ....

Where Scaled .... Date ....

Log No.	Length, Feet,	Diameter, Inches	Taper	Contents by Species					Defects, Kind, Amount Deducted, Overlengths
				Doug. Fir	Hem-lock	Cedar			
Brand	Totals—Species	Doug. Fir							
		Hem-lock							
		Cedar							
								Totals for Page	Trans. to Journal, Pg. .... / Scaled by

COLUMBIA RIVER LOG SCALING AND GRADING BUREAU LOG GRADING RULES FOR DOUGLAS FIR

No. 1 Logs.

No. 1 logs shall be logs which, in the judgment of the scaler, will be suitable for the manufacture of lumber in the grades of No. 2 clear or better to an amount of not less than 50 per cent of the scaled contents.

No. 1 logs shall contain not less than six annual rings to the inch in the outer portion of the log equal to one-half of the log content; and No. 1 logs shall be straight grained to the extent of a variation of not more than 2 inches to the lineal foot for a space of 6 lineal feet equidistant from each end of the log.

Rings, rot, or any defect that may be eliminated in the scale, are permitted in a No. 1 log providing their size and location do not prevent the log producing the required amount of No. 2 clear or better lumber.

A No. 1 log may contain a few small knots or well scattered pitch pockets as permitted in grades of No. 2 clear or better lumber; or may contain a very few grade defects so located that they do not prevent the production of the required amount of clear lumber.

No. 2 Logs.

No. 2 logs shall not be less than 12 feet in length, having defects which prevent their grading No. 1, but which, in the judgment of the scaler, will be suitable for the manufacture of lumber principally in the grades of No. 1 common or better.

No. 3 Logs.

No. 3 logs shall be not less than 12 feet in length, having defects which prevent their grading No. 2 but which, in the judgment of the scaler, will be suitable for the manufacture of inferior grades of lumber.

Cull Logs.

Cull logs shall be any logs which do not contain $33\frac{1}{3}$ per cent of sound lumber.

PUGET SOUND LOGGERS ASSOCIATION LOG SCALING AND GRADING RULES FOR DOUGLAS FIR

No. 1 Logs.

No. 1 logs shall be logs in the lengths of 16 to 32 feet and 30 inches in diameter inside the bark at the small end and logs 34 to 40 feet, 28 inches in diameter inside the bark at the small end, and shall be logs which in the judgment of the scaler shall contain at least 50 per cent of the scaled contents in lumber in the grades of No. 2 clear and better.

No. 2 Logs.

No. 2 logs shall be not less than 16 feet long and having defects which prevent its grading No. 1, but which in the judgment of the scaler will be suitable for the manufacture of lumber principally in the grades of merchantable and better.

No. 3 Logs.

No. 3 logs shall be not less than 16 feet long and having defects which prevent its cutting into higher grades and in the judgment of the scaler will be suitable for the manufacture of common lumber.

Cull Logs.

Cull logs shall be any logs which in the judgment of the scaler will not cut $33\frac{1}{3}$ per cent of sound lumber.

TABLES

TABLE I

SCHIFFEL FORMULA D.B.H. BASAL AREAS, 0.16 OF THE AREA OF A CIRCLE AT BREAST HEIGHT

Diameter, Inches	0.0 Square Feet	0.1 Square Feet	0.2 Square Feet	0.3 Square Feet	0.4 Square Feet	0.5 Square Feet	0.6 Square Feet	0.7 Square Feet	0.8 Square Feet	0.9 Square Feet
1	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.003
2	0.003	0.004	0.004	0.005	0.005	0.005	0.006	0.006	0.007	0.007
3	0.008	0.008	0.009	0.010	0.010	0.011	0.011	0.012	0.013	0.013
4	0.014	0.015	0.016	0.017	0.018	0.018	0.018	0.019	0.020	0.021
5	0.022	0.023	0.024	0.025	0.025	0.026	0.027	0.028	0.029	0.030
6	0.031	0.032	0.034	0.035	0.036	0.037	0.038	0.039	0.040	0.042
7	0.043	0.044	0.045	0.047	0.048	0.049	0.050	0.052	0.053	0.054
8	0.056	0.057	0.059	0.060	0.062	0.063	0.065	0.066	0.068	0.069
9	0.071	0.072	0.074	0.075	0.077	0.079	0.080	0.082	0.084	0.086
10	0.087	0.089	0.091	0.093	0.094	0.096	0.098	0.100	0.102	0.104
11	0.106	0.108	0.109	0.111	0.113	0.115	0.117	0.119	0.122	0.124
12	0.126	0.128	0.130	0.132	0.134	0.136	0.139	0.141	0.143	0.145
13	0.147	0.150	0.152	0.154	0.157	0.159	0.161	0.164	0.166	0.169
14	0.171	0.173	0.176	0.178	0.181	0.183	0.186	0.189	0.191	0.194
15	0.196	0.199	0.202	0.204	0.207	0.210	0.212	0.215	0.218	0.221
16	0.223	0.226	0.229	0.232	0.235	0.238	0.240	0.243	0.246	0.249
17	0.252	0.255	0.258	0.261	0.264	0.267	0.270	0.273	0.276	0.280
18	0.283	0.286	0.289	0.292	0.295	0.299	0.302	0.305	0.308	0.312
19	0.315	0.318	0.322	0.325	0.328	0.332	0.335	0.339	0.342	0.346
20	0.349	0.353	0.356	0.360	0.363	0.367	0.370	0.374	0.378	0.381
21	0.385	0.389	0.392	0.396	0.400	0.403	0.407	0.411	0.415	0.419
22	0.422	0.426	0.430	0.434	0.438	0.442	0.446	0.450	0.454	0.458
23	0.462	0.466	0.470	0.474	0.478	0.482	0.486	0.490	0.494	0.498
24	0.503	0.507	0.511	0.515	0.520	0.524	0.528	0.532	0.537	0.541
25	0.545	0.550	0.554	0.559	0.563	0.567	0.572	0.576	0.581	0.585
26	0.590	0.594	0.599	0.604	0.608	0.613	0.617	0.622	0.627	0.631
27	0.636	0.641	0.646	0.650	0.655	0.660	0.665	0.670	0.674	0.679
28	0.684	0.689	0.694	0.699	0.704	0.709	0.714	0.719	0.724	0.729
29	0.734	0.739	0.744	0.749	0.754	0.759	0.765	0.770	0.775	0.780
30	0.785	0.791	0.796	0.801	0.806	0.812	0.817	0.822	0.828	0.833
31	0.839	0.844	0.849	0.855	0.860	0.868	0.871	0.877	0.882	0.888
32	0.894	0.899	0.905	0.910	0.916	0.922	0.927	0.933	0.939	0.945
33	0.950	0.956	0.962	0.968	0.974	0.979	0.985	0.991	0.997	1.003
34	1.009	1.015	1.021	1.027	1.033	1.039	1.045	1.051	1.057	1.063
35	1.069	1.075	1.081	1.087	1.094	1.100	1.106	1.112	1.118	1.125
36	1.131	1.137	1.144	1.150	1.156	1.163	1.169	1.175	1.182	1.188
37	1.195	1.201	1.208	1.214	1.221	1.227	1.234	1.240	1.247	1.254
38	1.260	1.267	1.273	1.280	1.287	1.294	1.300	1.307	1.314	1.321
39	1.327	1.334	1.341	1.348	1.355	1.362	1.368	1.375	1.382	1.389
40	1.396	1.403	1.410	1.417	1.424	1.431	1.438	1.446	1.453	1.460

TABLE I—*Continued*

Diameter, Inches	0.0 Square Feet	0.1 Square Feet	0.2 Square Feet	0.3 Square Feet	0.4 Square Feet	0.5 Square Feet	0.6 Square Feet	0.7 Square Feet	0.8 Square Feet	0.9 Square Feet
41	1.467	1.474	1.481	1.488	1.496	1.503	1.510	1.517	1.525	1.532
42	1.539	1.547	1.554	1.561	1.569	1.576	1.584	1.591	1.599	1.606
43	1.614	1.621	1.629	1.636	1.644	1.651	1.659	1.667	1.674	1.682
44	1.689	1.697	1.705	1.713	1.720	1.728	1.736	1.744	1.751	1.759
45	1.767	1.775	1.783	1.791	1.799	1.807	1.815	1.823	1.831	1.839
46	1.847	1.855	1.863	1.871	1.879	1.887	1.895	1.903	1.911	1.920
47	1.928	1.936	1.944	1.952	1.961	1.969	1.977	1.986	1.994	2.002
48	2.011	2.019	2.027	2.037	2.044	2.053	2.061	2.070	2.078	2.087
49	2.095	2.104	2.112	2.121	2.130	2.138	2.147	2.156	2.164	2.173
50	2.182	2.190	2.199	2.208	2.217	2.226	2.234	2.243	2.252	2.261
51	2.270	2.279	2.288	2.297	2.306	2.315	2.324	2.333	2.342	2.351
52	2.360	2.369	2.378	2.387	2.396	2.405	2.414	2.424	2.433	2.442
53	2.451	2.461	2.470	2.479	2.488	2.498	2.507	2.516	2.526	2.535
54	2.545	2.554	2.564	2.573	2.583	2.592	2.602	2.611	2.621	2.630
55	2.640	2.649	2.659	2.669	2.678	2.688	2.698	2.707	2.717	2.727
56	2.737	2.746	2.756	2.766	2.776	2.786	2.796	2.806	2.815	2.825
57	2.835	2.845	2.855	2.865	2.875	2.885	2.895	2.905	2.915	2.926
58	2.936	2.946	2.956	2.966	2.976	2.986	2.997	3.007	3.017	3.027
59	3.038	3.048	3.058	3.069	3.079	3.089	3.100	3.110	3.121	3.131
60	3.142	3.152	3.163	3.173	3.184	3.194	3.205	3.215	3.226	3.237
61	3.247	3.258	3.269	3.279	3.290	3.301	3.311	3.322	3.333	3.344
62	3.355	3.365	3.376	3.387	3.398	3.409	3.420	3.431	3.442	3.453
63	3.464	3.475	3.486	3.497	3.508	3.519	3.530	3.541	3.552	3.563
64	3.574	3.586	3.597	3.608	3.619	3.630	3.642	3.653	3.664	3.676
65	3.687	3.698	3.710	3.721	3.733	3.744	3.755	3.767	3.778	3.790
66	3.801	3.813	3.824	3.836	3.848	3.859	3.871	3.882	3.894	3.906
67	3.917	3.929	3.941	3.953	3.964	3.976	3.988	4.000	4.012	4.023
68	4.035	4.047	4.059	4.071	4.083	4.095	4.107	4.119	4.131	4.143
69	4.155	4.167	4.179	4.191	4.203	4.215	4.227	4.239	4.252	4.264
70	4.276	4.288	4.301	4.313	4.325	4.337	4.350	4.362	4.374	4.387
71	4.399	4.412	4.424	4.436	4.449	4.461	4.474	4.486	4.499	4.511
72	4.524	4.536	4.549	4.562	4.574	4.587	4.600	4.612	4.625	4.638
73	4.650	4.663	4.676	4.689	4.702	4.714	4.727	4.740	4.753	4.766
74	4.779	4.792	4.805	4.818	4.831	4.844	4.857	4.870	4.883	4.896
75	4.909	4.922	4.935	4.948	4.961	4.975	4.988	5.001	5.014	5.027
76	5.041	5.054	5.067	5.080	5.094	5.107	5.120	5.134	5.147	5.161
77	5.174	5.187	5.201	5.214	5.228	5.241	5.255	5.269	5.282	5.296
78	5.309	5.323	5.337	5.350	5.364	5.378	5.391	5.405	5.419	5.433
79	5.446	5.460	5.474	5.488	5.502	5.515	5.529	5.543	5.557	5.571
80	5.585	5.599	5.613	5.627	5.641	5.655	5.669	5.683	5.697	5.711

TABLE II

Schiffel Formula Middle Diameter Basal Areas, 0.66 of the Area of a Circle at the Middle Height of the Tree

Diameter, Inches	0.0 Square Feet	0.1 Square Feet	0.2 Square Feet	0.3 Square Feet	0.4 Square Feet	0.5 Square Feet	0.6 Square Feet	0.7 Square Feet	0.8 Square Feet	0.9 Square Feet
1	0.004	0.004	0.005	0.006	0.007	0.008	0.009	0.010	0.012	0.013
2	0.014	0.016	0.017	0.019	0.021	0.023	0.024	0.026	0.028	0.030
3	0.032	0.035	0.037	0.039	0.042	0.044	0.047	0.049	0.052	0.055
4	0.058	0.061	0.064	0.067	0.070	0.073	0.076	0.080	0.083	0.086
5	0.090	0.094	0.097	0.101	0.105	0.109	0.113	0.117	0.121	0.125
6	0.130	0.134	0.138	0.143	0.147	0.152	0.157	0.162	0.166	0.171
7	0.176	0.182	0.187	0.192	0.197	0.202	0.208	0.213	0.219	0.225
8	0.230	0.236	0.242	0.248	0.254	0.260	0.266	0.273	0.279	0.285
9	0.292	0.298	0.305	0.311	0.318	0.325	0.332	0.339	0.346	0.353
10	0.360	0.367	0.375	0.382	0.389	0.397	0.405	0.412	0.420	0.428
11	0.436	0.444	0.452	0.460	0.468	0.476	0.484	0.493	0.501	0.510
12	0.518	0.527	0.536	0.545	0.554	0.563	0.572	0.581	0.590	0.599
13	0.608	0.618	0.627	0.637	0.646	0.656	0.666	0.676	0.686	0.696
14	0.706	0.716	0.726	0.736	0.746	0.757	0.767	0.778	0.788	0.799
15	0.810	0.821	0.832	0.843	0.854	0.865	0.876	0.887	0.899	0.910
16	0.922	0.933	0.945	0.956	0.968	0.980	0.992	1.004	1.016	1.028
17	1.040	1.053	1.065	1.077	1.090	1.102	1.115	1.128	1.140	1.153
18	1.166	1.179	1.192	1.205	1.219	1.232	1.245	1.259	1.272	1.286
19	1.299	1.313	1.327	1.341	1.355	1.369	1.383	1.397	1.411	1.426
20	1.440	1.454	1.469	1.483	1.498	1.513	1.528	1.542	1.557	1.572
21	1.587	1.603	1.618	1.633	1.649	1.664	1.680	1.695	1.711	1.726
22	1.742	1.758	1.774	1.790	1.806	1.822	1.839	1.855	1.871	1.888
23	1.904	1.921	1.937	1.954	1.971	1.988	2.005	2.022	2.039	2.056
24	2.073	2.091	2.108	2.126	2.143	2.161	2.178	2.196	2.214	2.232
25	2.250	2.268	2.286	2.304	2.322	2.341	2.359	2.378	2.396	2.415
26	2.433	2.452	2.471	2.490	2.509	2.528	2.547	2.566	2.585	2.605
27	2.624	2.644	2.663	2.683	2.703	2.722	2.742	2.762	2.782	2.802
28	2.822	2.842	2.863	2.883	2.903	2.924	2.944	2.965	2.986	3.006
29	3.027	3.048	3.069	3.090	3.111	3.133	3.154	3.175	3.197	3.218
30	3.240	3.261	3.283	3.305	3.327	3.349	3.371	3.393	3.415	3.437
31	3.459	3.482	3.504	3.527	3.549	3.572	3.595	3.617	3.640	3.663
32	3.686	3.709	3.732	3.756	3.779	3.802	3.826	3.849	3.873	3.896
33	3.920	3.944	3.968	3.992	4.016	4.040	4.064	4.088	4.112	4.137
34	4.161	4.186	4.210	4.235	4.260	4.285	4.309	4.334	4.359	4.385
35	4.410	4.435	4.460	4.486	4.511	4.537	4.562	4.588	4.614	4.639
36	4.665	4.691	4.717	4.743	4.769	4.796	4.822	4.848	4.875	4.901
37	4.928	4.955	4.981	5.008	5.035	5.062	5.089	5.116	5.143	5.171
38	5.198	5.225	5.253	5.280	5.308	5.336	5.363	5.391	5.419	5.447
39	5.475	5.503	5.532	5.560	5.588	5.616	5.645	5.673	5.702	5.731
40	5.760	5.788	5.817	5.846	5.875	5.904	5.934	5.963	5.992	6.022
41	6.051	6.081	6.110	6.140	6.170	6.200	6.230	6.260	6.290	6.320
42	6.350	6.380	6.411	6.441	6.471	6.502	6.533	6.563	6.594	6.625
43	6.656	6.687	6.718	6.749	6.780	6.812	6.843	6.874	6.906	6.937
44	6.969	7.001	7.033	7.064	7.096	7.128	7.160	7.193	7.225	7.257
45	7.290	7.322	7.354	7.387	7.420	7.452	7.485	7.518	7.551	7.584
46	7.617	7.650	7.683	7.717	7.750	7.784	7.817	7.851	7.884	7.918
47	7.952	7.986	8.020	8.054	8.088	8.122	8.156	8.190	8.225	8.259
48	8.294	8.328	8.363	8.404	8.433	8.467	8.502	8.537	8.573	8.608
49	8.643	8.678	8.714	8.749	8.785	8.820	8.856	8.892	8.927	8.963
50	8.999	9.035	9.072	9.108	9.144	9.180	9.217	9.253	9.290	9.326

TABLE III

Areas of Circles for Diameters of 1 Inch to 60 Inches

Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet
1.0	0.006	5.0	0.136	9.0	0.442	13.0	0.922	17.0	1.576	21.0	2.405
1.1	0.007	5.1	0.142	9.1	0.452	13.1	0.936	17.1	1.595	21.1	2.428
1.2	0.008	5.2	0.147	9.2	0.462	13.2	0.950	17.2	1.614	21.2	2.451
1.3	0.009	5.3	0.153	9.3	0.472	13.3	0.965	17.3	1.632	21.3	2.475
1.4	0.011	5.4	0.159	9.4	0.482	13.4	0.979	17.4	1.651	21.4	2.498
1.5	0.012	5.5	0.165	9.5	0.492	13.5	0.994	17.5	1.670	21.5	2.521
1.6	0.014	5.6	0.171	9.6	0.503	13.6	1.009	17.6	1.689	21.6	2.545
1.7	0.016	5.7	0.177	9.7	0.513	13.7	1.024	17.7	1.709	21.7	2.568
1.8	0.018	5.8	0.184	9.8	0.524	13.8	1.039	17.8	1.728	21.8	2.592
1.9	0.020	5.9	0.190	9.9	0.535	13.9	1.054	17.9	1.748	21.9	2.616
2.0	0.022	6.0	0.196	10.0	0.545	14.0	1.069	18.0	1.767	22.0	2.640
2.1	0.024	6.1	0.203	10.1	0.556	14.1	1.084	18.1	1.787	22.1	2.664
2.2	0.026	6.2	0.210	10.2	0.568	14.2	1.100	18.2	1.807	22.2	2.688
2.3	0.029	6.3	0.216	10.3	0.579	14.3	1.115	18.3	1.827	22.3	2.712
2.4	0.031	6.4	0.223	10.4	0.590	14.4	1.131	18.4	1.847	22.4	2.737
2.5	0.034	6.5	0.230	10.5	0.601	14.5	1.147	18.5	1.867	22.5	2.761
2.6	0.037	6.6	0.238	10.6	0.613	14.6	1.163	18.6	1.887	22.6	2.786
2.7	0.040	6.7	0.245	10.7	0.625	14.7	1.179	18.7	1.907	22.7	2.810
2.8	0.043	6.8	0.252	10.8	0.636	14.8	1.195	18.8	1.928	22.8	2.835
2.9	0.046	6.9	0.260	10.9	0.648	14.9	1.211	18.9	1.948	22.9	2.860
3.0	0.049	7.0	0.267	11.0	0.660	15.0	1.227	19.0	1.969	23.0	2.885
3.1	0.052	7.1	0.275	11.1	0.672	15.1	1.244	19.1	1.990	23.1	2.910
3.2	0.056	7.2	0.283	11.2	0.684	15.2	1.260	19.2	2.011	23.2	2.936
3.3	0.059	7.3	0.291	11.3	0.697	15.3	1.277	19.3	2.032	23.3	2.961
3.4	0.063	7.4	0.299	11.4	0.709	15.4	1.294	19.4	2.053	23.4	2.986
3.5	0.067	7.5	0.307	11.5	0.721	15.5	1.310	19.5	2.074	23.5	3.012
3.6	0.071	7.6	0.315	11.6	0.734	15.6	1.327	19.6	2.095	23.6	3.038
3.7	0.075	7.7	0.323	11.7	0.747	15.7	1.344	19.7	2.117	23.7	3.064
3.8	0.079	7.8	0.332	11.8	0.760	15.8	1.362	19.8	2.138	23.8	3.089
3.9	0.083	7.9	0.340	11.9	0.772	15.9	1.379	19.9	2.160	23.9	3.115
4.0	0.087	8.0	0.349	12.0	0.785	16.0	1.396	20.0	2.182	24.0	3.142
4.1	0.092	8.1	0.358	12.1	0.799	16.1	1.414	20.1	2.204	24.1	3.168
4.2	0.096	8.2	0.367	12.2	0.812	16.2	1.431	20.2	2.226	24.2	3.194
4.3	0.101	8.3	0.376	12.3	0.825	16.3	1.449	20.3	2.248	24.3	3.221
4.4	0.106	8.4	0.385	12.4	0.839	16.4	1.467	20.4	2.270	24.4	3.247
4.5	0.111	8.5	0.394	12.5	0.852	16.5	1.485	20.5	2.292	24.5	3.275
4.6	0.115	8.6	0.403	12.6	0.866	16.6	1.503	20.6	2.315	24.6	3.301
4.7	0.121	8.7	0.413	12.7	0.880	16.7	1.521	20.7	2.337	24.7	3.328
4.8	0.126	8.8	0.422	12.8	0.894	16.8	1.539	20.8	2.360	24.8	3.335
4.9	0.131	8.9	0.432	12.9	0.908	16.9	1.558	20.9	2.383	24.9	3.382

TABLE III—*Continued*

Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet	Diameter, Inches	Area, Square Feet
25.0	3.409	26.4	3.801	27.8	4.215	29.1	4.619	35.0	6.681	48.0	12.566
25.1	3.436	26.5	3.830	27.9	4.246	29.2	4.650	36.0	7.069	49.0	13.095
25.2	3.464	26.6	3.860			29.3	4.682	37.0	7.467		
25.3	3.491	26.7	3.888	28.0	4.276	29.4	4.714	38.0	7.876	50.0	13.635
25.4	3.519	26.8	3.917	28.1	4.307	29.5	4.746	39.0	8.296	51.0	14.186
25.5	3.547	26.9	3.947	28.2	4.337	29.6	4.779			52.0	14.748
25.6	3.574			28.3	4.368	29.7	4.811	40.0	8.727	53.0	15.321
25.7	3.602	27.0	3.976	28.4	4.399	29.8	4.844	41.0	9.168	54.0	15.904
25.8	3.631	27.1	4.006	28.5	4.430	29.9	4.876	42.0	9.621		
25.9	3.659	27.2	4.035	28.6	4.461			43.0	10.085	55.0	16.499
		27.3	4.065	28.7	4.493	30.0	4.909	44.0	10.559	56.0	17.104
26.0	3.687	27.4	4.095	28.8	4.524	31.0	5.241			57.0	17.721
26.1	3.715	27.5	4.125	28.9	4.555	32.0	5.585	45.0	11.045	58.0	18.348
26.2	3.744	27.6	4.155			33.0	5.940	46.0	11.541	59.0	18.986
26.3	3.773	27.7	4.185	29.0	4.587	34.0	6.305	47.0	12.048		

TABLE IV

VOLUMES OF FRUSTUMS OF CONES. SCALED WITH SCRIBNER RULE IN 16-FOOT LOGS DOWN TO 8-INCH TOPS

	HEIGHT IN NUMBER OF LOGS									
D.B.H.	1½	2	3	4	5	6	7	8	9	10
10	43	74	115	159						
11	44	80	128	175						
12	46	86	137	192						
13	47	91	150	212	271					
14	48	96	165	232	300					
15	50	103	179	257	331	405				
16	52	111	195	279	366	449	528			
17	54	120	210	311	406	496	598	684		
18	56	129	231	338	438	548	650	756	855	968
19	...	137	253	363	485	591	707	822	938	1065
20	...	146	270	395	530	651	780	908	1030	1165
21	...	160	291	435	572	710	828	982	1126	1278
22	...	174	317	472	618	775	931	1095	1227	1391
23	...	182	342	510	675	843	998	1155	1329	1507
24	...	191	364	550	720	895	1097	1265	1439	1725
25	...	204	391	584	772	972	1182	1346	1532	1760
26	...	217	426	624	836	1052	1250	1458	1669	1886
27	...	231	449	666	901	1105	1337	1566	1804	2038
28	...	245	476	719	954	1194	1441	1699	1916	2199
29	...	259	508	755	1026	1285	1552	1848	2062	2337
30	...	272	539	809	1092	1363	1639	1908	2208	2482
31	...	292	569	868	1160	1446	1732	2019	2324	2626
32	...	312	595	926	1233	1536	1837	2161	2451	2802
33	...	324	636	982	1299	1608	1930	2274	2582	2965
34	...	336	682	1029	1355	1704	2059	2410	2772	3103
35	...	351	717	1072	1424	1808	2128	2527	2897	3262
36	...	366	754	1117	1509	1896	2272	2654	3041	3433
37	...	388	792	1180	1587	1987	2374	2773	3171	3591
38	...	409	827	1243	1662	2085	2473	2920	3340	3773
39	...	422	851	1296	1745	2127	2613	3063	3493	3954
40	...	436	887	1331	1805	2236	2743	3195	3683	4164
41	...	464	929	1401	1878	2366	2874	3375	3864	4395
42	...	491	973	1455	1940	2501	3037	3515	4030	4545
43	...	511	1018	1506	2040	2637	3153	3647	4214	4739
44	...	532	1048	1593	2174	2730	3243	3846	4399	5000
45	...	...	1084	1658	2269	2838	3384	4011	4629	5202

TABLE V

VOLUME TABLE—DOUGLAS FIR, IN FEET, B.M., BASED ON D.B.H. AND 30-FOOT HEIGHT CLASSES

D.B.H.	to 75	76 to 105	106 to 135	136 to 165	166 to 195	196 to 225	226 to 255	256 Up
10	80	100	130	160				
12	100	140	190	240	310			
14	140	200	250	330	430	540		
16	190	220	320	440	540	690		
18	240	320	410	550	680	840	980	
20	290	380	480	680	850	1,010	1,170	
22	350	460	580	810	980	1,190	1,360	
24	430	550	700	910	1,150	1,390	1,580	
26	510	640	810	1060	1,340	1,600	1,820	
28	590	750	930	1250	1,550	1,820	2,080	
30	680	860	1080	1440	1,770	2,080	2,310	
32	780	980	1230	1620	2,020	2,300	2,610	
34	890	1100	1400	1830	2,280	2,590	2,930	
36	1000	1240	1570	2040	2,550	2,700	3,270	3,630
38	....	1400	1760	2260	2,850	3,230	3,630	4,020
40	....	1560	1980	2510	3,170	3,600	4,030	4,410
42	....	1740	2190	2720	3,510	3,970	4,040	4,870
44	....	1910	2420	2950	3,810	4,360	4,870	5,390
46	....	....	2660	3360	4,180	4,770	5,200	5,870
48	....	....	2920	3690	4,570	5,200	5,730	6,330
50	....	....	3190	4030	4,950	5,650	6,200	6,860
52	....	....	3480	4400	5,400	6,090	6,680	7,470
54	....	....	....	4800	5,900	6,140	7,210	8,070
56	....	....	....	5200	6,350	7,070	7,760	8,660
58	....	....	....	5620	6,800	7,600	8,320	9,330
60	....	....	....	6150	7,260	8,150	8,910	10,010
62	....	....	....	6420	7,710	8,650	9,570	10,740
64	....	....	....	6790	8,280	9,220	10,260	11,590
66	....	....	....	7150	8,730	9,870	10,960	12,470
68	....	....	....	7470	9,240	10,510	11,770	13,330
70	....	....	....	7790	9,870	11,200	12,540	14,250
72	....	....	....	....	10,260	11,880	13,320	15,240
74	....	....	....	....	10,670	12,600	14,190	16,160
76	....	....	....	....	11,050	13,440	15,050	17,190
78	....	....	....	....	11,410	14,140	15,840	17,850
80	....	....	....	....	11,760	14,850	16,680	18,540
82	....	....	....	....	.....	15,480	17,400	19,230
84	....	....	....	....	.....	16,030	18,010	19,980
86	....	....	....	....	.....	16,510	18,550	20,640
88	....	....	....	....	.....	16,930	19,040	21,240
90	....	....	....	....	.....	17,370	19,500	21,810
92	....	....	....	....	.....	.....	19,920	22,340
94	....	....	....	....	.....	.....	20,300	22,810
96	....	....	....	....	.....	.....	20,680	23,210
98	....	....	....	....	.....	.....	21,020	23,610
100	....	....	....	....	.....	.....	21,360	23,970

NOTE.—Tables V, VI, VII, VIII are based upon data collected in the lower slope, Douglas fir-cedar type of King and Snohomish Counties in Western Washington. The trees were scaled by the Scribner Decimal C Rule to a point 8 inches in diameter at the tops inside the bark. The Douglas fir table is based upon the measurement of about 600 trees and the other tables each are based upon the measurement of about 300 trees.

TABLE VI

VOLUME TABLE—WESTERN RED CEDAR—IN FEET B.M. BASED ON D.B.H. AND 30-FOOT HEIGHT CLASSES

D.B.H.	to 75	76 to 105	106 to 135	136 to 165	166 to 195	196 to 225	226 to 255	256 Up
12	90	102						
14	120	192	210					
16	158	209	265					
18	196	256	322					
20	235	302	386	510	570			
22	275	352	456	590	710			
24	....	406	528	700	875			
26	....	460	598	818	1,045			
28	....	557	670	910	1,200			
30	....	629	749	1016	1,360			
32	....	....	836	1145	1,560			
34	....	....	940	1303	1,780			
36	....	....	1122	1498	1,990			
38	....	....	1272	1718	2,200			
40	....	....	1700	1945	2,425	2,650	2,875	
42	....	....	1855	2178	2,670	2,875	3,080	
44	....	....	2015	2412	2,915	3,165	3,415	
46	....	....	2180	2768	3,175	3,475	3,775	
48	....	....	2340	2940	3,435	3,800	4,165	
50	....	....	2500	3480	3,690	4,090	4,490	
52	....	....	2670	3500	3,950	4,425	4,900	
54	....	....	2840	3740	4,225	4,750	5,275	
56	....	....	3010	3815	4,500	5,100	5,700	
58	....	....	3190	4160	4,800	5,470	6,140	
60	....	....	3375	4390	5,105	5,825	6,545	
62	....	....	3555	4615	5,410	6,200	6,990	
64	....	....	3750	4850	5,725	6,560	7,395	
66	....	....	3925	5075	6,030	6,920	7,810	
68	....	....	4100	5300	6,340	7,280	8,220	
70	....	....	4280	5520	6,640	7,600	8,560	
72	....	....	4470	5750	6,935	7,950	8,965	
74	....	....	4650	5970	7,220	8,275	9,330	
76	....	....	4825	6190	7,505	8,600	9,695	
78	....	....	5010	6425	7,795	8,925	10,055	
80	....	....	5200	6670	8,080	9,250	10,420	
82	....	....	....	6925	8,400	9,575	10,750	
84	....	....	....	7200	8,700	9,975	11,250	
86	....	....	....	7475	9,000	10,350	11,700	
88	....	....	. .	7750	9,300	10,750	12,200	
90	....	....	....	8000	9,600	11,200	12,800	
92	....	....	....	8265	9,940	11,575	13,210	
94	....	....	....	8550	10,265	11,980	13,695	
96	....	....	....	8850	10,600	12,350	14,100	
98	....	....	....	9125	10,900	12,675	14,450	
100	....	....	....	9400	11,200	13,000	14,800	

TABLE VII

VOLUME TABLE—SILVER FIR—IN FEET, B.M., BASED ON D.B.H. AND 30-FOOT HEIGHT CLASSES

D.B.H.	To 75	76 to 105	106 to 135	136 to 165	166 to 195	196 Up
10	60	65	75			
12	95	110	135			
14	140	160	250			
16	190	240	360	500		
18	240	315	470	610		
20	310	405	580	770	1,190	
22	380	510	700	920	1,360	
24	480	620	840	1,110	1,540	
26	590	740	950	1,290	1,730	
28	700	870	1100	1,470	1,920	
30	820	1020	1270	1,660	2,140	2,660
32	930	1170	1450	1,870	2,370	2,900
34	1090	1380	1650	2,100	2,620	3,170
36	1240	1530	1860	2,360	2,900	3,450
38	1390	1720	2090	2,650	3,190	3,760
40	1560	1930	2330	2,880	3,490	4,080
42	1730	2160	2590	3,200	3,840	4,440
44	1900	2400	2880	3,500	4,180	4,750
46	2080	2640	3170	3,790	4,520	5,090
48	2260	2890	3480	4,110	4,860	5,440
50	2450	3150	3790	4,410	5,200	5,780
52	2630	3420	4100	4,730	5,540	6,140
54	....	3670	4430	5,080	5,580	6,500
56	....	3950	4750	5,460	6,240	6,850
58	....	4220	5090	5,820	6,570	7,230
60	....	4500	5450	6,200	6,940	7,620
62	....	4770	5800	6,570	7,290	8,020
64	....	....	6150	6,960	7,670	8,440
66	....	....	6510	7,340	8,060	8,970
68	....	....	6880	7,710	8,460	9,310
70	....	....	7250	8,110	8,850	9,750
72	....	....	7610	8,500	9,260	10,200
74	....	....	....	8,870	9,650	10,630
76	....	....	....	9,230	10,030	11,030
78	....	....	....	9,570	10,380	11,380
80	....	....	....	9,900	10,700	11,750
82	....	....	....	10,200	11,010	12,080
84	....	....	....	10,470	11,320	12,380
86	....	....	....	....	11,600	12,600
88	....	....	....	....	11,860	12,920
90	....	....	....	....	12,100	13,150
92	....	....	....	....	12,330	13,380
94	....	....	....	....	....	13,600
96	....	....	....	....	....	13,820
98	....	....	....	....	....	14,020
100	....	....	....	....	....	14,220

TABLE VIII

Volume Table—Western Hemlock—in Feet, B.M., Based on D.B.H. and 30-foot Height Classes

D.B.H.	To 75	76 to 105	106 to 135	136 to 165	166 to 195	196 Up
10	50	60	80			
12	80	100	140			
14	130	150	220			
16	200	220	300	480		
18	260	280	390	590		
20	350	370	490	710		
22	430	460	580	850	1200	
24	510	550	700	1000	1380	
26	590	650	830	1170	1600	
28	....	760	980	1360	1840	
30	....	900	1140	1560	2100	2,710
32	....	1050	1300	1780	2350	3,050
34	....	1200	1500	2040	2750	3,460
36	....	1390	1710	2300	3150	3,910
38	....	....	1940	2650	3560	4,420
40	....	....	2190	2850	3980	4,920
42	....	....	2480	3200	4410	5,400
44	....	....	2800	3600	4850	5,840
46	....	....	3150	4080	5300	6,220
48	....	....	3550	4580	5700	6,570
50	....	....	3950	5070	6120	6,890
52	....	....	4430	5480	6450	7,180
54	....	....	4860	5840	6750	7,260
56	....	....	5260	6170	7030	7,640
58	....	....	....	6460	7270	7,860
60	....	....	....	6750	7500	8,060
62	....	....	....	7020	7710	8,270
64	....	....	....	7260	7920	8,440
66	....	....	....	7460	8110	8,620
68	....	....	....	7640	8290	8,790
70	....	....	....	7820	8450	8,950
72	....	....	....	....	8610	9,100
74	....	....	....	....	8770	9,230
76	....	....	....	....	8920	9,360
78	....	....	....	....	9060	9,480
80	....	....	....	....	9180	9,570
82	....	....	....	....	9290	9,660
84	....	....	....	....	9400	9,740
86	....	....	....	....	9500	9,820
88	....	....	....	....	9580	9,900
90	....	....	....	....	9670	9.970
92	....	....	....	....	....	10,030
94	....	....	....	....	....	10,100
96	....	....	....	....	....	10,160
98	....	....	....	....	....	10,210
100	....	....	....	....	....	10,270

TABLE IX

Scribner Decimal "C" Log Rule for Logs 6 to 32 Feet in Length

Diameter, Inches	Length—Feet													
	6	8	10	12	14	16	18	20	22	24	26	28	30	32
	Contents, Board Feet in Tens													
6	0.5	0.5	1	1	1	2	2	2	3	3	3	4	4	5
7	0.5	1	1	2	2	3	3	3	4	4	4	5	5	6
8	1	1	2	2	2	3	3	3	4	4	5	6	6	7
9	1	2	3	3	3	4	4	4	5	6	6	7	8	9
10	2	3	3	3	4	6	6	7	8	9	9	10	11	12
11	2	3	4	4	5	7	8	8	9	10	11	12	13	14
12	3	4	5	6	7	8	9	10	11	12	13	14	15	16
13	4	5	6	7	8	10	11	12	13	15	16	17	18	19
14	4	6	7	9	10	11	13	14	16	17	19	20	21	23
15	5	7	9	11	12	14	16	18	20	21	23	25	27	28
16	6	8	10	12	14	16	18	20	22	24	26	28	30	32
17	7	9	12	14	16	18	21	23	25	28	30	32	35	37
18	8	11	13	16	19	21	24	27	29	32	35	37	40	43
19	9	12	15	18	21	24	27	30	33	36	39	42	45	48
20	11	14	17	21	24	28	31	35	38	42	45	49	52	56
21	12	15	19	23	27	30	34	38	42	46	49	53	57	61
22	13	17	21	25	29	33	38	42	46	50	54	58	63	67
23	14	19	23	28	33	38	42	47	52	57	61	66	71	75
24	15	21	25	30	35	40	45	50	55	61	66	71	76	81
25	17	23	29	34	40	46	52	57	63	69	75	80	86	92
26	19	25	31	37	44	50	56	62	69	75	82	88	94	100
27	21	27	34	41	48	55	62	68	75	82	89	96	103	110
28	22	29	36	44	51	58	65	73	80	87	95	102	109	116
29	23	31	38	46	53	61	68	76	84	91	99	107	114	122
30	25	33	41	49	57	66	74	82	90	99	107	115	123	131
31	27	36	44	53	62	71	80	89	98	106	115	124	133	142
32	28	37	46	55	64	74	83	92	101	110	120	129	138	147
33	29	39	49	59	69	78	88	98	108	118	127	137	147	157
34	30	40	50	60	70	80	90	100	110	120	130	140	150	160
35	33	44	55	66	77	88	98	109	120	131	142	153	164	175
36	35	46	58	69	81	92	104	115	127	138	150	161	173	185
37	39	51	64	77	90	103	116	129	142	154	167	180	193	206
38	40	54	67	80	93	107	120	133	147	160	174	187	200	214
39	42	56	70	84	98	112	126	140	154	168	182	196	210	224
40	45	60	75	90	105	120	135	150	166	181	196	211	226	241
41	48	64	79	95	111	127	143	159	175	191	207	223	238	254
42	50	67	84	101	117	134	151	168	185	201	218	235	252	269
43	52	70	87	105	122	140	157	174	192	209	227	244	262	279
44	56	74	93	111	129	148	166	185	204	222	241	259	278	296
45	57	76	95	114	133	152	171	190	209	228	247	266	286	304
46	59	79	99	119	139	159	178	198	218	238	258	278	297	317
47	62	83	104	124	145	166	186	207	228	248	269	290	310	331
48	65	86	108	130	151	173	194	216	238	260	281	302	324	346
49	67	90	112	135	157	180	202	225	247	270	292	314	337	359
50	70	94	117	140	164	187	211	234	257	281	304	328	351	374
51	73	97	122	146	170	195	219	243	268	292	315	341	365	389
52	76	101	127	152	177	202	228	253	278	304	329	354	380	405
53	79	105	132	158	184	210	237	263	289	316	341	368	395	421
54	82	109	137	164	191	218	246	273	300	328	355	382	410	437
55	85	113	142	170	198	227	255	283	312	340	368	397	425	453
56	88	118	147	176	206	235	264	294	323	353	382	411	441	470
57	91	122	152	183	213	244	274	304	335	365	396	426	457	487
58	95	126	158	189	221	252	284	315	347	379	410	442	473	505
59	98	131	163	196	229	261	294	327	359	392	425	457	490	523
60	101	135	169	203	237	270	304	338	372	406	439	473	507	541

TABLE IX—*Continued*

Diameter, Inches	Length—Feet													
	6	8	10	12	14	16	18	20	22	24	26	28	30	32
	Contents, Board Feet in Tens													
61	105	140	175	210	245	280	315	350	385	420	455	490	525	560
62	108	145	181	217	253	289	325	362	398	434	470	506	542	579
63	112	149	187	224	261	299	336	373	411	448	485	523	560	597
64	116	154	193	232	270	309	348	387	425	464	503	541	580	619
65	119	159	199	239	279	319	358	398	438	478	518	558	597	637
66	123	164	206	247	288	329	370	412	453	494	535	576	617	659
67	127	170	212	254	297	339	381	423	466	508	550	593	635	677
68	131	175	219	262	306	350	393	437	480	524	568	611	655	699
69	135	180	226	271	316	361	406	452	497	542	587	632	677	723
70	139	186	232	279	325	372	419	465	512	558	605	651	698	744
71	144	192	240	287	335	383	430	478	526	574	622	670	717	765
72	148	197	247	296	345	395	444	493	543	592	641	691	740	789
73	152	203	254	305	356	406	457	508	559	610	661	712	762	813
74	157	209	261	314	366	418	471	523	576	628	680	733	785	837
75	161	215	269	323	377	430	484	538	592	646	700	754	807	861
76	166	221	277	332	387	443	498	553	609	664	719	775	830	885
77	171	228	285	341	398	455	511	568	625	682	739	796	852	909
78	176	234	293	351	410	468	527	585	644	702	761	819	878	936
79	180	240	301	361	421	481	541	602	662	722	782	842	902	963
80	185	247	309	371	432	494	556	618	680	742	804	866	927	989
81	190	254	317	381	444	508	572	635	699	762	826	889	953	1016
82	196	261	326	391	456	521	586	652	717	782	847	912	977	1043
83	201	268	335	401	468	535	601	668	735	802	869	936	1002	1069
84	206	275	343	412	481	549	618	687	755	824	893	961	1030	1099
85	210	281	351	421	491	561	631	702	772	842	912	982	1052	1123
86	215	287	359	431	503	575	646	718	790	862	934	1006	1077	1149
87	221	295	368	442	516	589	663	737	810	884	958	1031	1105	1179
88	226	301	377	452	527	603	678	753	829	904	979	1055	1130	1205
89	231	308	385	462	539	616	693	770	847	924	1001	1078	1155	1232
90	236	315	393	472	551	629	708	787	865	944	1023	1101	1180	1259
91	241	322	402	483	563	644	725	805	886	966	1047	1127	1208	1288
92	246	329	411	493	575	657	739	822	904	986	1068	1150	1232	1315
93	251	335	419	503	587	671	754	838	922	1006	1090	1174	1257	1341
94	257	343	428	514	600	685	771	857	942	1028	1114	1199	1285	1371
95	262	350	437	525	612	700	788	875	963	1050	1138	1225	1313	1400
96	268	357	446	536	625	715	804	893	983	1072	1161	1251	1340	1429
97	273	364	455	546	637	728	819	910	1001	1092	1183	1274	1365	1456
98	278	371	464	557	650	743	835	928	1021	1114	1207	1300	1392	1485
99	284	379	473	568	663	757	852	947	1041	1136	1231	1325	1420	1515
100	289	386	482	579	675	772	869	965	1062	1158	1255	1351	1448	1544
101	295	393	492	590	688	787	885	983	1082	1180	1278	1377	1475	1573
102	301	401	502	602	702	803	903	1003	1104	1204	1304	1405	1505	1605
103	307	409	512	614	716	819	921	1023	1126	1228	1330	1433	1535	1637
104	313	417	522	626	730	835	939	1043	1148	1252	1356	1461	1565	1669
105	319	425	532	638	744	851	957	1063	1170	1276	1382	1489	1595	1701
106	325	433	542	650	758	867	975	1083	1192	1300	1408	1517	1625	1733
107	331	442	553	663	773	884	995	1105	1216	1326	1437	1547	1658	1768
108	337	450	563	675	788	900	1013	1125	1238	1350	1463	1575	1688	1800
109	344	459	573	688	803	917	1032	1147	1261	1376	1491	1605	1720	1835
110	350	467	583	700	817	933	1050	1167	1283	1400	1517	1633	1750	1867
111	356	475	594	713	832	951	1069	1188	1307	1426	1545	1664	1782	1901
112	362	483	604	725	846	967	1087	1208	1329	1450	1571	1692	1812	1933
113	369	492	615	738	861	984	1107	1230	1353	1476	1599	1722	1845	1968
114	375	501	626	751	876	1001	1126	1252	1377	1502	1627	1752	1877	2003
115	382	509	637	764	891	1019	1146	1273	1401	1528	1655	1783	1910	2037
116	389	519	648	778	908	1037	1167	1297	1426	1556	1686	1815	1945	2075
117	396	528	660	792	924	1056	1188	1320	1452	1584	1716	1848	1980	2112
118	403	537	672	806	940	1075	1209	1343	1478	1612	1746	1881	2015	2149
119	410	547	683	820	957	1093	1230	1367	1503	1640	1777	1913	2050	2187
120	417	556	695	834	973	1112	1251	1390	1529	1668	1807	1946	2085	2224

TABLE X*

Yield for Even-aged Stands of Douglas Fir on Quality 1 Soils, Based on Two-site Qualities for the Type, Namely, Western Foothills of the Cascade Mountains in Washington and Oregon. (Read from Curves.)

Age	No. of Trees per Acre	Total Basal Area	Diameter of Average Tree	Height of Average Tree	Yield per Acre	Average Annual Growth per Acre in Each Decade	Yield per Acre	Average Annual Growth per Acre in Each Decade
Years		Sq. Ft.	Inches	Feet	Cu. Ft.	Cu. Ft.	Ft. B.M.	Ft. B.M.
10	.....	.....	.....	.....	1,000			
20	990	116	4.6	32.0	2,150	115		
30	580	149	6.9	46.0	3,550	140		
40	410	177	8.9	59.0	5,400	185	12,400	
50	340	199	10.4	69.5	7,550	215	28,000	1560
60	265	218	12.3	82.0	9,650	210	41,000	1300
70	208	234	14.4	95.0	11,500	185	51,700	1070
80	107	247	16.5	107.5	13,100	160	61,100	940
90	137	261	18.7	120.5	14,400	130	70,300	920
100	115	275	20.9	134.5	15,600	120	79,800	950
110	100	288	23.0	147.0	16,750	115	90,300	1050
120	92	301	24.5	156.5	17,800	105	101,500	1120
130	90	312	25.2	161.0	18,850	105	113,000	1150
140	88	323	25.9	166.0	19,900	105	122,600	960

Based on $252\frac{2}{16}$ acres (361 sample plots).

Note.—Including only Douglas fir, western hemlock, grand fir, and Sitka spruce; over 95 per cent of the trees are Douglas fir.

The yield in cubic feet includes the contents of the whole stem of all the trees; that in board feet includes only the merchantable contents of trees 12 inches and more in diameter at breast height, taken to a top diameter of 8 inches inside the bark.

*From Cir. No. 175, Forest Service, U. S. Dept. Agr., Growth and Management of Douglas Fir in the Pacific Northwest, by T. T. Munger.

DATA SERIES

DATA SERIES I

Douglas Fir Stem Measurements

Collected in the West Coast Lower Slope Type of Washington and Oregon

D.B.H.	Total Height	Mer. Length to 8 inches	No. of 16.2-foot Sections to 8 Inches	Volume, B.M., 16.2-foot Sections to 8 Inches	Volume, Cubic Feet (stem)	Used Length	Volume, B.M. (as cut into logs by logger)
31.1	180.6	140.0	8¾	1401	255.5	120.3	
27.1	141.2	116.6	7¼	1046	185.3	67.0	
25.0	129.2	97.6	6	710	130.0	71.9	
24.5	119.8	92.1	5¾	730	144.3	70.6	
22.2	159.1	117.5	7¼	590	120.2	97.6	
24.2	148.7	114.1	7¼	890	172.1	96.2	
27.0	130.2	115.6	7¼	1000	174.4	105.5	
31.0	179.7	151.1	9½	1550	253.1	79.5	
24.2	150.3	96.1	6	540	120.4	78.6	
13.8	139.8	86.0	5½	204	53.2	80.0	
31.2	178.1	......	......	......	314.2	123.2	1550
27.0	158.1	85.6	5¼	......	255.5	80.6	1256
17.0	115.6	......	......	......	72.5	65.0	336
23.5	161.4	139.8	8¾	1290	206.2	127.4	
26.0	153.7	121.1	7½	1140	202.3	99.0	
27.0	158.1	......	......	......	255.5	83.6	980
32.5	184.2	126.3	8	......	271.8	126.3	1510
12.5	113.2	69.6	4¼	160	40.3	408.8	140
17.0	124.8	68.2	4¼	240	76.9	37.1	160
35.0	183.0	157.4	9¾	3620	394.9	112.2	2590
19.8	123.9	85.8	5¼	690	101.4	81.0	440
16.7	127.3	......	......	......	78.1	64.6	440
26.1	174.7	135.3	8½	1162	193.7	101.9	1000
32.7	175.0	149.4	9¼	1720	285.9	131.2	1660
17.1	152.1	103.0	6½	360	86.3	70.3	340
26.3	149.3	......	......	......	198.7	105.0	1040
29.0	156.7	......	......	......	231.1	85.9	1180
39 5	222.4	......	......	......	321.5	135.9	2650
12 1	115.2	......	......	......	......	36.6	80
17.8	101.8	64.8	4	260	61.0	49.4	190
12.1	97.0	43.2	2¾	80	23.7	24.7	60
11.2	96.3	41.4	2½	70	24.5	36.1	50
18.7	110.0	......	......	......	73.5	61.0	330
27.1	160.7	136.1	8½	......	182.7	103.2	870
29.0	173.2	134.6	8½	......	201.6	87.6	1860
32.0	166.8	146.8	9¼	......	260.8	103.9	1430
30.9	199.4	162.0	10	1920	305.4	139.4	1990
38.5	225.4	162.0	10	2780	406.8	162.0	2710
35.0	254.3	194.4	12	4030	515.2	162.0	3840
33.5	226.3	178.2	11	2610	426.1	116.2	2180
29.3	197.7	162.0	10	1820	225.0	114.1	1560

DATA SERIES I—*Continued*

D.B.H.	Total Height	Mer. Length to 8 Inches	No. of 16.2-foot Sections to 8 Inches	Volume, B.M., 16.2-foot Sections to 8 Inches	Volume, Cubic Feet (stem)	Used Length	Volume, B.M. (as cut into logs by logger)
44.0	216.6	178.2	11	4210	625.3	133.2	3130
23.3	182.5	145.8	9	910	182.6	98.9	890
31.0	200.5	162.0	10	2110	383.9	105.7	1660
37.5	214.8	162.0	10	2750	422.5	131.1	2460
45.5	215.0	194.4	12	5190	721.2	135.1	4870
24.0	168.0	145.8	9	1330	203.2	104.6	1100
44.4	266.8	178.2	11	4210	614.5	131.4	3560
39.4	196.8	194.4	12	4590	655.2	157.8	4380
23.5	201.5	145.8	9	1480	238.2	102.3	1080
19.1	190.2	129.6	8	520	122.3	97.2	510
32.7	208.3	178.2	11	2390	375.1	102.1	1860
19.2	179.5	113.4	7	680	134.2	65.3	470
36.2	199.2	178.2	11	3280	469.5	118.2	2650
26.0	184.7	145.8	9	1260	207.6	106.3	1080
25.0	198.3	162.0	10	1610	252.9	145.1	1570
33.0	191.0	162.0	10	2310	344.1	130.4	1980
21.2	165.5	113.4	7	680	110.6	97.5	500
31.6	222.0	162.0	10	2320	326.9	148.0	2290
26.3	146.1	129.6	8	1000	189.6	97.5	820
22.9	144.0	129.6	8	780	124.2	72.5	620
13.5	147.0	81.0	5	220	49.6	64.9	160
24.4	181.0	129.6	8	910	149.2	129.9	820
24.4	180.1	145.8	9	990	178.3	130.0	880
25.0	189.1	145.8	9	1310	188.4	129.6	1150
30.5	191.5	178.2	11	2420	381.2	162.0	2191
17.5	135.7	113.4	7	560	103.1	97.7	430
26.5	183.6	129.6	8	1040	188.4	129.6	860
27.5	181.0	129.6	8	1340	219.5	98.0	1240
21.1	134.7	113.4	7	770	140.3	80.0	710
23.8	160.0	145.8	9	1120	191.2	102.0	1100
21.7	147.0	113.4	7	1040	110.5	104.0	1010
32.5	197.3	162.0	10	2640	394.0	149.5	2390
22.5	143.3	113.4	7	500	104.4	89.1	370
17.9	114.5	81.0	5	350	91.2	74.0	300
32.0	183.3	162.0	10	1890	314.8	140.0	1740
27.8	204.2	162.0	10	1630	215.0	125.5	1420
28.0	195.0	162.0	10	1910	253.3	119.3	1530
21.0	163.0	129.6	8	900	158.1	146.0	780
26.5	181.4	162.0	10	1710	275.6	145.2	1670
30.6	194.0	162.0	10	1970	314.4	106.5	1916
28.5	191.8	162.0	10	2110	319.4	143.1	1660
24.5	176.5	145.8	9	1260	215.7	145.3	1100
24.5	192.8	162.0	10	1570	252.1	135.8	1210
24.5	195.3	162.0	10	1650	257.7	81.3	1130
37.5	208.6	178.2	11	3330	609.3	104.6	2390

DATA SERIES 1—*Continued*

D.B.H.	Total Height	Mer. Length to 8 Inches	No. of 16.2-foot Sections to 8 Inches	Volume, B.M., 16.2-foot Sections to 8 Inches	Volume, Cubic Feet (stem)	Used Length	Volume, B.M. (as cut into logs by logger)
25.5	188.6	145.8	9	1440	242.7	70.1	960
23.5	174.0	145.8	9	1190	197.2	100.0	890
38.0	215.4	194.4	12	3670	464.2	162.0	3240
32.0	183.9	162.0	10	1820	277.2	109.0	1280
26.0	147.1	129.6	8	1070	148.9	94.2	890
32.4	208.4	178.2	11	2500	378.8	137.0	2200
29.0	198.1	162.0	10	1780	298.6	101.6	1540
34.5	205.7	178.2	11	2800	424.2	133.7	2330
34.6	206.4	178.2	11	2930	369.8	155.1	2830
29.0	182.3	129.6	8	1730	246.9	113.5	1640
27.5	195.4	162.0	10	1470	210.9	100.4	1220
17.2	180.1	113.4	7	570	131.6	72.9	500
41.3	196.3	178.2	11	3940	542.8	153.1	3600
29.2	204.7	158.0	$9\frac{3}{4}$	1680	270.0	147.5	1550
23.2	187.9	156.0	$9\frac{1}{2}$	1130	189.6	145.5	950
31.0	204.5	178.2	11	1950	346.4	148.3	1850
26.0	186.9	145.8	9	910	170.9	145.3	880
24.2	151.6	113.4	7	900	132.2	99.4	810
15.0	125.0	81.0	5	270	47.4	67.9	230
15.6	137.8	81.0	5	340	73.3	60.0	230
41.2	241.0	194.4	12	4610	688.9	186.6	4360
18.0	157.7	97.2	6	420	87.5	89.2	340
36.5	210.6	162.0	10	3940	446.3	117.6	2510
31.0	194.3	162.0	10	1660	292.3	142.1	1490
33.0	199.3	178.2	11	2040	320.7	98.6	1500
37.3	226.5	178.2	11	3180	466.2	151.3	2820
32.3	190.9	162.0	10	2110	269.6	123.4	1760
47.2	229.8	210.6	13	5810	699.2	167.8	5110
31.9	225.2	178.2	11	1910	299.5	162.3	1830
24.8	184.9	145.8	9	1340	167.5	103.0	1080
25.0	193.2	162.0	10	1360	187.0	97.4	860
34.0	222.9	194.4	12	3700	428.8	131.9	2710
31.0	203.6	162.0	10	1990	294.2	66.0	1000
37.8	211.0	194.4	12	4250	589.6	154.9	4000
35.2	195.0	178.2	11	3240	464.6	131.0	3120
38.5	209.2	162.0	10	2920	331.4	133.3	2720
34.0	205.0	178.2	11	2590	413.5	120.1	2140
32.0	205.0	178.2	11	2890	360.0	135.6	2050
17.0	130.5	97.2	6	490	88.5	96.0	360
40.0	189.8	45.8	9	2930	455.4	67.8	2060
31.5	195.0	162.0	10	1980	332.6	65.0	1210
29.5	166.4	129.6	8	1310	224.9	60.8	890
36.1	193.2	162.0	10	2830	422.4	114.8	2240
19.8	150.1	113.4	7	660	116.3	101.9	590
40.0	195.0	178.2	11	2900	569.0	66.5	2470

DATA SERIES I—*Continued*

D.B.H.	Total Height	Mer. Length to 8 inches	No. of 16.2-foot Sections to 8 Inches	Volume, B.M., 16.2-foot Sections to 8 Inches	Volume, Cubic Feet (stem)	Used Length	Volume, B.M. (as cut into logs by logger)
50.0	233.5	210.2	13	7310	703.9	130.0	5900
26.0	176.4	145.8	9	1310	238.6	112.0	1140
32.0	196.5	162.0	10	2540	376.1	136.0	2340
25.0	151.3	145.8	9	1190	158.4	108.2	790
39.5	224.9	176.2	11	3970	623.4	129.9	3610
29.7	194.0	162.0	10	2170	340.2	103.0	1720
39.0	206.5	176.2	11	3980	577.4	110.0	3590
20.9	190.0	145.8	9	850	150.8	129.6	790
18.9	118.4	81.0	5	450	85.6	64.8	360
14.8	107.0	56.8	3½	200	53.3		
15.4	102.0	64.8	4	270	57.5		
14.8	95.5	60.8	3¾	210	46.5		
14.7	104.0	62.8	4	230	50.3		
13.0	91.0	48.6	3	160	36.1		
14.5	90.0	46.6	3½	150	36.3		
13.2	103.0	52.8	3¼	140	38.1		
11.6	95.0	40.6	2½	80	28.1		
15.7	99.5	60.8	3¾	220	51.1		
16.0	104.0	64.8	4	270	59.3		
13.6	102.0	50.8	3¼	110	40.3		
13.6	99.0	52.8	3¼	140	39.3		
14.0	90.0	46.6	3	150	35.4		
11.6	92.0	38.6	2½	70	28.2		
13.8	87.0	46.4	3	150	35.8		
13.5	92.0	48.6	3	130	34.8		
11.5	94.0	42.6	2¾	80	28.3		
11.6	86.0	40.6	2½	80	26.4		
16.2	117.0	64.8	4	310	71.7		
14.0	94.0	54.8	4	180	44.7		
13.6	95.0	54.6	4	150	41.1		
11.2	69.0	16.2	1	40	17.9		
13.6	108.0	58.8	3¾	180	44.8		
13.5	85.5	42.6	3¾	130	32.5		
12.0	93.0	48.6	3	150	33.4		
11.2	90.0	40.6	2½	90	28.9		
12.4	95.0	48.6	3	160	38.1		
11.7	83.0	42.6	2¾	110	26.4		
12.1	106.6	28.6	1¾	160	38.4		
13.0	80.0	48.6	3	150	28.4		
15.8	102.0	60.8	3¾	210	51.6		
15.8	97.0	71.0	4½	230	68.1		
16.6	104.0	64.8	4	270	58.2		
14.3	114.0	56.8	3½	200	49.9		
15.2	96.0	54.8	3½	170	44.1		
14.3	122.0	56.8	3½	200	47.2		

DATA SERIES I—*Continued*

D.B.H.	Total Height	Mer. Length to 8 Inches	No. of 16.2-foot Sections to 8 Inches	Volume, B.M., 16.2-foot Sections to 8 Inches	Volume, Cubic Feet (stem)	Used Length	Volume, B.M. (as cut into logs by logger)
16.0	135.3	91.2	5¾	410	77.8		
15.2	147.9	93.2	5¾	400	82.9		
10.6	85.0	38.6	2½	80	24.9		
11.6	94.0	42.6	2¾	110	29.7		
13.8	136.5	81.0	5	320	66.4		
14.5	84.0	42.6	2¾	110	34.0		
12.0	73.5	32.4	2	90	24.0		
15.8	102.0	60.8	3¾	210	51.6		
14.9	117.0	64.8	4	270	57.6		
11.0	90.0	40.6	2½	90	27.2		
11.6	94.0	42.6	2¾	110	29.7		
11.1	83.0	38.6	2½	70	23.0		
11.6	87.0	46.6	3	120	28.7		
17.0	145.0	97.2	6	410	82.3		
16.0	136.0	91.2	5¾	360	73.0		
18.0	133.0	97.2	6	450	89.3		
17.8	132.0	97.2	6	460	86.1		
16.5	142.0	95.2	6	370	79.2		
21.4	162.0	127.6	8	860	145.8		
23.5	167.0	121.6	7½	1030	186.8		
21.0	152.0	107.4	6¾	680	126.4		
20.0	152.0	113.4	7	630	120.1		
21.0	159.0	107.4	6¾	650	129.8		
17.5	157.0	97.2	6	450	94.5		
23.5	170.0	129.6	8	1230	207.5		
22.2	130.0	109.4	6¾	670	132.5		
19.0	140.0	97.2	6	530	116.9		
19.8	152.0	107.4	6¾	680	123.6		
18.6	137.0	113.4	7	580	96.9		
19.2	152.0	107.4	6¾	490	99.8		
20.0	159.0	113.4	7	760	140.0		
17.5	122.0	81.0	5	400	76.5		
17.7	138.0	97.2	6	570	99.3		
17.1	147.0	91.2	5¾	440	86.2		
19.0	148.0	111.2	7	660	115.9		
18.8	144.0	97.2	6	490	99.6		
31.7	174.0	145.8	9	1940	301.1		
26.0	182.0	141.8	8¾	1300	212.4		
26.2	161.0	135.8	8½	1300	195.2		
22.6	162.0	129.6	8	890	144.9		
25.0	171.0	129.6	8	1600	255.3		
27.0	156.0	111.4	7	690	153.1		
33.4	207.0	176.2	11	3300	477.3		
33.5	210.0	176.2	11	3490	487.6		
21.7	183.7	145.8	9	950	167.8		

DATA SERIES I—*Continued*

D.B.H.	Total Height	Mer. Length to 8 Inches	No. of 16.2-foot Sections to 8 Inches	Volume, B.M., 16.2-foot Sections to 8 Inches	Volume, Cubic Feet (stem)	Used Length	Volume, B.M. (as cut into logs by logger)
19.2	138.2	113.4	7	690	102.5		
22.8	178.6	129.6	8	910	164.6		
21.6	176.6	139.8	8½	1040	169.1		
31.5	199.5	162.0	10	1980	311.8		
24.5	190.8	143.8	9	1260	219.2		
24.3	210.2	160.2	10	1620	263.0		
24.4	183.0	145.8	9	1230	208.2		
36.1	197.6	160.2	10	2670	426.9		
36.0	204.2	174.2	10½	2810	430.4		
32.5	206.8	174.2	10½	2580	401.3		
33.9	207.0	162.0	10	2720	443.1		
24.7	192.0	143.8	9	1400	233.4		
34.2	200.6	162.0	10	2620	395.9		
27.5	202.2	143.8	9	1530	265.0		
17.8	165.0	97.9	6	420	86.8		
27.5	202.2	143.8	9	1530	264.9		
11.7	83.0	42.6	2¾	110	26.4		
13.5	85.5	43.6	2¾	130	35.8		
16.5	117.0	72.8	4½	340	70.6		
15.5	112.0	64.8	4	280	59.4		
19.5	135.0	97.2	6	1610	110.6		
20.0	149.1	97.2	6	660	126.2		
27.0	161.2	123.6	7¾	1410	224.8		
16.0	136.7	91.2	5¾	360	74.2		
16.3	126.2	81.0	5	460	89.4		
15.6	136.3	93.2	5¾	360	75.7		
16.0	136.8	81.0	5	340	75.0		
15.6	136.9	97.2	6	440	83.9		
13.9	116.8	60.8	3¾	190	47.5		
12.9	127.4	56.8	3½	150	39.7		
14.1	130.2	75.0	4¾	270	59.8		
14.5	137.2	91.2	5¾	360	71.9		
27.0	184.6	162.0	10	1780	288.6		
31.5	206.2	176.2	11	2730	404.1		
27.6	207.8	129.6	8	1460	305.2		
20.3	188.8	143.8	9	1020	177.3		
21.2	158.0	113.4	7	620	118.9		
30.2	180.0	111.4	7	1310	244.6		
21.4	160.0	125.6	7¾	800	144.9		
38.2	209.9	174.2	10¾	3870	559.2		
25.0	191.3	160.0	10	1380	240.6		
25.0	176.0	145.8	9	1590	236.2		
25.9	180.6	145.8	9	1540	218.3		
41.6	200.0	129.6	8	3330	528.3		
30.0	201.5	162.0	10	1730	286.9		

DATA SERIES I—*Continued*

D.B.H.	Total Height	Mer. Length to 8 Inches	No. of 16.2-foot Sections to 8 Inches	Volume, B.M., 16.2-foot Sections to 8 Inches	Volume, Cubic Feet (stem)	Used Length	Volume, B.M. (as cut into logs by logger)
18.9	162.0	113.4	7	600	116.0		
17.8	151.3	107.4	6¾	470	93.8		
19.7	162.0	117.6	7¼	770	132.1		
17.8	165.0	97.2	6	420	86.8		
32.5	185.8	162.0	10	2510	360.9		
38.5	211.5	162.0	10	3180	471.4		
34.4	217.0	162.0	10	3010	480.7		
26.8	160.0	111.4	7	930	176.6		
26.5	200.6	162.0	10	1840	299.2		
28.1	196.0	162.0	10	1960	323.7		
22.2	157.5	129.6	8	1010	161.0		
41.0	204.0	139.8	8¾	3150	488.9		
27.7	160.2	......	......	......	......	106.9	960
27.8	171.1	......	......	......	......	123.1	1250
30.5	149.2	......	......	......	......	101.0	1120
33.9	171.7	......	......	......	......	114.3	1120
34.0	168.8	......	......	......	......	129.8	1560
35.0	182.0	......	......	......	......	99.0	1830
37.0	167.0	......	......	......	......	114.0	1940
37.2	176.9	......	......	......	......	133.4	2360
38.1	178.0	......	......	......	......	111.0	2700
16.3	118.2	......	......	......	......	70.4	260
16.5	109.3	......	......	......	......	66.8	260
18.2	138.4	......	......	......	......	70.4	300
22.0	135.3	......	......	......	......	64.5	460
22.4	169.8	......	......	......	......	101.8	560
58.0	226.6	......	......	......	......	158.8	6280
53.5	219.7	......	......	......	......	153.5	7660
18.3	126.5	......	......	......	......	65.3	290
22.5	132.5	......	......	......	......	72.7	600
49.0	258.6	......	......	......	......	154.2	4890
57.1	255.2	......	......	......	......	164.4	4820
60.0	213.5	......	......	......	......	161.5	8170
57.0	205.5	......	......	......	......	128.0	6440
20.0	121.5	......	......	......	......	58.2	270
18.0	129.5	......	......	......	......	108.0	320
47.1	179.3	......	......	......	......	167.6	5070
30.5	182.0	......	......	......	......	149.2	1670
47.0	210.6	......	......	......	......	148.0	4580
39.0	189.3	......	......	......	......	114.5	2490
36.0	193.2	......	......	......	......	117.0	2510
52.2	202.4	......	......	......	......	111.7	4490
30.1	200.0	......	......	......	......	139.0	1570
43.5	230.0	......	......	......	......	121.7	3440
41.8	184.8	......	......	......	......	131.6	2510

DATA SERIES I—*Continued*

D.B.H.	Total Height	Mer. Length to 8 inches	No. of 16.2-foot Sections to 8 Inches	Volume, B.M., 16.2-foot Sections to 8 Inches	Volume, Cubic Feet (stem)	Used Length	Volume, B.M. (as cut into logs by logger)
22.0	175.1	......	......	......	......	102.6	750
42.2	199.5	......	......	......	......	122.1	3310
47.0	202.3	......	......	......	......	134.5	6240
44.6	237.9	......	......	......	......	134.3	3080
42.4	214.6	......	......	......	......	135.1	3130
48.5	244.0	......	......	......	......	145.1	4030
45.5	221.2	......	......	......	......	122.6	3760
41.0	194.2	......	......	......	......	135.1	3290
42.2	182.5	......	......	......	......	101.8	2820
52.3	229.8	......	......	......	......	125.3	3980
48.4	212.9	......	......	......	......	130.9	3180
45.4	208.2	......	......	......	......	127.0	3350
42.5	216.3	......	......	......	......	156.6	4280
30.5	189.6	......	......	......	......	124.0	1510
35.7	187.2	......	......	......	......	127.8	2290
54.0	239.8	......	......	......	......	179.2	6770
59.7	......	......	......	......	......	175.6	6140
40.0	......	......	......	......	......	148.9	3870
52.2	......	......	......	......	......	186.7	8490
60.5	......	......	......	......	......	141.8	8150
45.5	......	......	......	......	......	179.6	4451
47.0	......	......	......	......	......	138.4	6050
54.0	......	......	......	......	......	136.4	5490
52.0	......	......	......	......	......	112.6	5500
53.0	......	......	......	......	......	151.6	6890
49.5	......	......	......	......	......	151.6	5690
48.0	......	......	......	......	......	192.6	4270
48.0	......	......	......	......	......	130.8	3510
49.0	......	......	......	......	......	147.3	5090
54.0	......	......	......	......	......	195.2	7130
49.0	......	......	......	......	......	142.5	5850
52.0	......	......	......	......	......	153.8	7140
48.0	......	......	......	......	......	154.9	3820
46.0	......	......	......	......	......	112.1	3640
38.0	......	......	......	......	......	155.8	2410
44.0	......	......	......	......	......	144.4	4310
44.0	......	......	......	......	......	154.2	4640
41.0	......	......	......	......	......	124.3	3610
52.0	......	......	......	......	......	176.8	8930
46.0	......	......	......	......	......	172.1	6130
46.0	......	......	......	......	......	156.3	4760
60.0	......	......	......	......	......	155.6	8580

DATA SERIES II

Measurements of Periodic Growth at the Stump

Collected in Pure Western Yellow Pine Stands at Manitou Park, Colo.

Tree No.	D.B.H., Inches	Periodic Growth, Inches * (Radius)	Tree No.	D.B.H., Inches	Periodic Growth, Inches * (Radius)	Tree No.	D.B.H., Inches	Periodic Growth, Inches * (Radius)
1	14.0	0.20	18	11.0	0.40	37	11.0	0.60
2	9.5	0.30	19	9.0	0.55	38	13.0	0.50
3	6.0	0.55	21	13.0	0.20	39	9.0	0.60
4	13.5	0.30	22	11.5	0.40	40	10.0	0.50
5	17.0	0.20	24	5.2	0.55	42	7.0	0.55
6	10.6	0.25	25	8.0	0.50	44	6.5	0.50
8	10.0	0.45	26	9.0	0.40	45	6.5	0.60
9	11.0	0.40	27	18.0	0.25	46	9.1	0.50
10	18.0	0.30	29	11.0	0.40	47	7.5	0.60
11	16.0	0.30	30	10.2	0.45	48	9.1	0.30
12	18.0	0.30	31	12.5	0.40	49	10.0	0.35
15	12.0	0.30	33	16.0	0.30	50	11.5	0.40
16	7.0	0.50	34	10.5	0.85	51	18.0	0.20
17	12.5	0.35	36	11.2	0.50	52	5.9	0.60

* Measurements represent outermost ten rings on average radius.

DATA SERIES III

Douglas Fir Stump Analyses

Collected in Pure, Even-aged, Second-growth Stands in Western Washington on Site Quality 1

Tree No.	D.B.H.	Total Age	Distance on Average Radius Center to Each 10th Ring—Inches. Decades													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	31.1	131	$^6/2.0$	4.3	5.8	6.9	7.7	8.4	9.4	10.5	11.8	12.6	13.2	13.8	14.0	
2	25.0	136	$^2/0.3$	2.8	4.1	5.3	6.4	7.3	8.1	8.7	9.2	9.7	10.2	10.6	11.0	11.6
3	30.2	135	2.3	4.5	5.7	6.7	7.8	8.8	9.4	10.3	11.1	12.1	12.7	13.9	14.8	
4	18.9	137	$^3/0.4$	2.4	4.0	5.0	5.6	6.2	6.6	7.0	7.2	7.35	7.5	8.0	8.35	8.5
5	19.2	131	$^7/1.5$	3.9	5.4	6.0	6.6	7.0	7.6	7.9	8.05	8.2	8.3	8.5	8.7	
6	22.8	141	$^6/1.5$	3.7	5.2	6.2	7.2	8.0	8.6	9.2	9.7	10.2	10.4	10.5	10.7	10.8
7	21.7	140	$^5/1.1$	3.1	4.3	5.1	5.6	6.1	6.9	7.6	8.0	8.45	8.85	9.2	9.45	9.7
8	25.0	140	$^5/1.0$	3.3	4.9	5.9	6.8	7.4	8.1	8.7	9.3	9.8	10.3	10.8	11.2	11.5
9	27.6	141	$^6/0.7$	3.1	5.1	6.1	7.0	7.7	8.1	9.8	10.2	11.0	11.7	12.2	12.9	13.2
10	27.0	140	$^5/1.2$	4.3	5.9	6.7	7.4	8.0	8.9	9.6	10.3	11.1	11.7	12.3	12.8	13.2
11	33.5	139	$^3/0.4$	2.7	4.8	6.2	7.3	8.3	9.5	10.8	11.8	12.7	13.7	14.4	15.1	15.7
12	26.8	132	$^7/1.8$	4.0	5.2	6.3	7.2	8.2	9.0	9.8	10.8	11.3	11.7	12.1	12.5	
13	32.5	139	$^4/0.9$	3.3	5.1	6.2	7.5	8.8	10.0	11.0	11.9	12.6	13.35	14.0	14.65	15.2
14	31.5	143	$^8/2.5$	5.8	7.7	8.8	9.5	10.1	10.6	11.1	11.5	11.9	12.5	13.4	13.7	14.0
15	24.3	134	2.3	4.7	6.1	7.0	8.0	9.0	9.8	10.3	10.9	11.4	11.85	12.1	12.2	
16	24.5	135	1.2	3.4	5.2	6.6	7.9	9.1	10.1	11.0	11.6	11.9	12.2	12.5	12.8	
17	27.5	135	1.6	3.2	5.1	6.4	7.3	8.2	9.0	9.7	10.4	11.0	12.1	12.7	12.9	
18	27.5	136	$^1/0.2$	2.9	4.4	5.5	6.7	7.6	8.5	9.4	10.1	10.9	11.35	11.85	12.2	12.6
19	25.9	139	$^4/0.8$	4.0	6.2	7.3	8.2	9.1	9.7	10.5	11.0	11.3	11.75	12.05	12.3	12.5
20	24.4	139	$^4/0.9$	3.9	5.4	6.3	6.9	7.1	8.3	8.8	9.5	10.0	10.4	10.85	11.15	11.3
21	30.2	126	2.0	4.0	5.8	6.8	7.6	8.3	9.1	9.7	10.6	11.2	11.9	12.2		
22	22.0	132	$^6/1.6$	3.8	5.7	6.6	7.2	7.7	8.3	8.5	8.7	9.0	9.3	9.6	10.0	
23	10.0	38	$^4/0.7$	2.5	3.7	4.8										
24	10.6	42	$^7/1.1$	2.9	4.1	5.0										
25	7.2	36	$^1/0.05$	0.8	2.1	3.4										

26	12.0	39	$^{6}/0.9$	3.4	5.3	6.3										
27	14.9	40	$^{5}/0.8$	3.4	6.0	7.9										
28	15.2	39	$^{5}/1.2$	3.85	5.8	7.5										
29	15.0	40	$^{5}/1.1$	3.7	6.2	7.8										
30	19.1	59	$^{4}/0.6$	3.3	5.2	6.5	7.7	9.0								
31	15.4	59	$^{4}/0.6$	2.6	4.4	5.6	6.5	7.2								
32	10.1	55	$^{1}/0.2$	1.4	2.7	3.6	4.0	4.75								
33	13.8	58	$^{3}/0.3$	2.5	4.1	5.0	5.6	6.1								
34	10.4	54	1.9	3.5	4.3	4.6	4.7									
35	15.7	58	$^{3}/0.5$	2.6	4.7	6.1	6.9	7.9								
36	10.3	59	$^{5}/0.8$	2.2	3.1	4.1	4.7	4.9								
37	13.8	59	$^{5}/1.0$	2.7	3.7	4.5	5.4	6.3								
38	14.2	63	$^{9}/1.5$	3.4	4.6	5.6	6.1	6.6								
39	20.8	58	$^{4}/1.0$	4.0	5.8	7.3	8.2	9.5								
40	7.0	35	$^{1}/0.1$	1.8	2.5	3.3										
41	10.4	54	1.9	3.5	4.3	4.6	4.7									
42	30.0	126	2.6	6.0	7.8	9.3	10.3	11.0	11.6	12.2	12.4	12.5	12.6	12.7		
43	41.0	126	2.5	5.0	6.6	7.8	9.1	10.2	11.7	13.0	14.2	14.9	16.5	17.5		
44	41.6	122	$^{6}/1.4$	3.9	6.1	7.8	9.4	11.0	12.3	13.3	14.6	15.7	16.9	17.85		
45	33.5	141	$^{6}/2.1$	4.9	7.1	8.2	8.8	9.7	10.8	11.6	12.2	13.1	13.8	14.5	15.1	15.7
46	16.6	56	$^{1}/0.3$	2.5	4.3	6.2	7.2	8.15								
47	20.9	56	2.3	4.35	6.5	8.0	9.25									
48	15.0	57	$^{2}/0.4$	2.7	4.3	5.4	6.0	6.8								
49	17.1	57	$^{2}/0.3$	2.3	4.6	6.2	7.2	8.1								
50	16.1	57	$^{2}/0.5$	3.1	4.7	6.0	6.6	7.3								
51	16.5	55	$^{1}/0.3$	2.6	4.5	6.0	6.9	7.6								
52	16.4	57	$^{2}/0.6$	3.2	5.3	6.7	7.3	7.5								
53	15.2	56	$^{1}/0.2$	3.6	5.2	6.3	7.45									
54	20.7	57	$^{2}/0.4$	2.8	4.9	6.6	7.9	9.1								
55	13.5	54	$^{9}/1.5$	2.9	4.5	5.4	6.2									
56	18.0	55	1.5	3.7	6.3	7.9	8.7									
57	11.4	53	$^{9}/1.1$	2.5	4.2	4.9	5.4									
58	10.2	55	1.6	2.8	4.0	4.5	4.8									
59	21.5	52	$^{8}/1.9$	4.0	6.3	8.0	9.55									

DATA SERIES IV

Height Growth Measurements

Collected in Pure, Even-aged, Second-growth Stands of Douglas Fir in Western Washington on Site Quality 1

(Average stump height 2 feet)

Tree No.	Total Age, Years	Total Height, Feet	Number Rings at Various Height Above the Ground					
			No. Rings	Height Above Ground, Feet	No. Rings	Height Above Ground, Feet	No. Rings	Height Above Ground, Feet
1	55	111.0	43	16				
2	39	93.0	20	47				
3	40	117.0	22	45				
4	55	111.0	49	14				
5	53	111.0	48	14				
6	39	106.0	22	44.5				
7	48	124.0	43	16				
8	131	192.2	118	37	109	70		
9	136	176.0	122	34	106	74		
10	135	190.8	118	36.0	63	157.0		
11	137	162.0	114	35.0	86	110.0		
12	131	138.2	119	27.0	97	75.0	77	118.0
14	140	191.3	114	44.0	68	140.0		
16	140	184.6	116	48.0	105	83.0	54	157.6
17	132	160.0	114	43.0	97	118.0		
20	134	210.2	109	68.0	84	133.0		
21	135	212.6	111	52.0	80	131.0		
22	136	202.2	121	36.0	103	85.0	78	144.0
25	139	180.6	82	130.0				
26	140	183.7	115	51.5				
27	135	210.5	82	128.5				

DATA SERIES V

Complete Stem Analysis. SPECIES, *Western Yellow Pine*
LOCALITY, *Manitou Park, Colo.*

Regular Volume Measurements							As Used by Logger				
Section	Age, Years	Length, Feet	D.I.B., Inches	Bark Width, Inches	D.O.B., Inches	Volume	Length, Feet	D.I.B., Inches	Volume, B.M.		
1 St.	239	2.0	16.8	0.8	18.4						
2	166	16.0	15.6	0.5	16.6						
3	151	16.0	12.8								
4		26.0				Top					
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											

Tree No. 67 SUMMARY Plot No............

D.B.H.	Total Age	Total Height	Mer. Length	No. of Logs	Volume, Cubic Feet	Volume, B.M.	Used Length	Clear Length	Volume, B.M.		
18.0	245	60						18			

Name, F. H. Rice. Date, 7, 17, '09.

Tree No. 67.

Cross Sect.	Distance on Average Radius from Heart to Each 10th Ring—Inches. (Count in, Measure Out)																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 St.	9/0.5	0.85	1.25	1.45	1.90	2.20	2.80	3.45	4.05	4.25	4.55	4.90	5.30	5.60	6.00	6.40	7.20	7.25	7.3
2	6/0.4	1.00	2.10	3.00	3.50	4.15	4.65	5.00	5.40	5.80	6.10	6.40	6.65	7.00	7.20	7.45	7.80		
3	1/0.15	0.85	1.50	2.00	2.55	3.10	3.65	4.05	4.40	4.70	5.00	5.30	5.45	5.50	5.90	6.40			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
11																			
12																			
13																			
14																			

Cross Sect.	Distance on Average Radius from Heart to Each 10th Ring—Inches. (Count in, Measure Out)																		
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1 St.	7.60	7.70	7.85	8.10	8.40														
2																			
3																			
4																			

DATA SERIES V—*Continued*

Regular Volume Measurements							As Used by Logger				
Section	Age, Years	Length, Feet	D.I.B., Inches	Bark Width, Inches	D.O.B., Inches	Volume	Length, Feet	D.I.B., Inches	Volume, B.M.		
1 St.	204	2.7	15.0	0.60	16.2						
2	192	16.0	13.8	0.35	14.5						
3	163	16.0	10.0	0.25	10.5						
4	94	16.0	6.6	0.20	7.0						
5		12.4				Top					
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

Tree No. 116 SUMMARY Plot No...........

D.B.H.	Total Age	Total Height	Mer. Length	No. of Logs	Volume, Cubic Feet	Volume, B.M.	Used Length	Clear Length	Volume, B.M.		
16	212	63.1						22.7			

Name, F. P. McKown. Date, 7, 17, '09.

Tree No. 116.

Cross Sect.	Distance on Average Radius from Heart to Each 10th Ring—Inches. (Count in, Measure out)																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 St.	0.2	0.4	0.7	0.95	1.20	1.50	2.00	2.30	2.60	2.90	3.35	3.90	4.20	4.50	5.00	5.40	5.80	6.10	6.50
2	0.3	0.7	1.10	1.50	1.80	2.20	2.50	2.80	3.20	3.45	3.70	4.00	4.30	4.60	4.90	5.25	5.60	5.90	6.40
3	0.3	0.8	1.10	1.40	1.60	1.90	2.30	2.60	2.90	3.15	3.40	3.65	3.90	4.15	4.35	4.70	5.00	.....	.....
4	0.25	0.5	0.9	1.30	1.70	2.00	2.30	2.60	2.90	3.30	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Cross Sect.	Distance on Average Radius from Heart to Each 10th Ring—Inches. (Count in, Measure Out)																		
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1 St.	7.20	7.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	6.90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

DATA SERIES V—*Continued*

Regular Volume Measurements							As Used by Logger				
Section	Age, Years	Length, Feet	D.I.B., Inches	Bark Width, Inches	D.O.B., Inches	Volume	Length, Feet	D.I.B., Inches	Volume, B.M.		
1 St.	104	1.6	9.4	0.6	10.2						
2	67	16.0	6.8	0.3	7.4						
3	25	16.0	2.0	0.1	2.2						
4		4.0				Top					
5											
6											
7											
8											
9											
10											
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											

Tree No. 18 SUMMARY Plot No............

D.B.H.	Total Age	Total Height	Mer. Length	No of Logs	Volume, Cubic Feet	Volume, B.M.	Used Length	Clear Length	Volume, B.M.		
10	109	37.6						18			

Name, O. J. Staunchfield. Date, 7, 19, '09.

Tree No. 18.

Cross Sect.	Distance on Average Radius from Heart to Each 10th Ring—Inches. (Count in, Measure Out)																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1 St.	4/0.1	0.6	1.15	1.90	2.30	2.65	3.00	3.40	3.70	4.25	4.70	......	......	......	......	......	......	......	......
2	7/0.65	1.2	1.70	2.00	2.40	2.90	3.40	......	......	......	......	......	......	......	......	......	......	......	......
3	5/0.2	0.7	1.00	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
5	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
6	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
7	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
8	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
9	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
10	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
11	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
12	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
13	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
14	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

Cross Sect.	Distance on Average Radius from Heart to Each 10th Ring—Inches. (Count in, Measure Out)																		
	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
1	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
2	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
3	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......
4	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

DATA SERIES VI

STATISTICS OF SAMPLE ACRE PLOTS IN PURE EVEN-AGED STANDS OF DOUGLAS FIR

Data collected by the U. S. Forest Service, 1909 and 1911, in Western Washington and Oregon.*

SITE QUALITY I

Location and Plot Number	No. of Trees	Age of Stand, Years	Volume		Basal Area, Square Feet	D.B.H. of Average Tree, Inches	Height of Average Tree, Feet
			Cubic Feet	Feet, B.M.			
Saddle Mt., Siuslaw, N.F.							
96	208	38	4,704	15,604	131	10.7	88
95	347	38	6,327	19,920	179	9.8	85
97	231	38	5,285	17,878	148	10.8	88
89	263	38	6,813	23,847	190	11.5	91
94	386	38	7,288	20,514	195	11.2	89
88	186	38	6,306	25,263	172	10.5	87
91	252	38	7,022	24,397	194	11.9	92
Cougar Cr., Ore.							
44	367	51	7,266	17,481	179	9.5	95
49	262	51	9,888	35,766	227	12.6	110
48	286	51	9,668	30,036	206	11.5	105
58	547	51	9,818	14,389	254	9.2	93
55	347	51	9,192	28,305	218	10.7	101
62	373	51	9,253	22,675	211	10.2	98
Bacon Creek, Washington, N. F.							
167	265	62	8,119	28,779	185	11.3	108
160	233	62	11,725	49,757	261	14.3	117
163	302	62	12,073	45,097	271	13.8	115
149	241	62	11,469	48,012	255	13.9	116
161	186	62	10,740	47,816	238	15.3	120
165	182	62	10,139	43,030	217	14.8	118
Parmelia Trail, Santiam, N. F.							
125	260	107	18,324	103,134	368	16.1	135
129	228	107	20,500	120,096	394	17.8	141
139	177	107	19,168	111,741	366	19.5	148
138	219	107	18,709	102,64	363	17.4	140
137	216	107	19,421	113,284	370	17.7	141
136	176	107	22,589	140,570	432	21.2	155
Lucia, Wash.							
7	84	121	19,021	108,860	342	27.3	173
1	70	121	14,429	79,250	263	26.2	169
5	95	121	25,560	154,517	458	29.7	178
504	93	121	24,047	141,234	431	29.1	177
510	72	121	16,476	95,458	296	27.4	173
502	67	121	18,841	112,992	337	30.3	180

* This table includes all species on the acre plot except cedar. The latter is considered an understory. Douglas fir is the predominating species, with scattering hemlock, firs, spruce, pines and hardwoods. All trees to 2 inches D.B.H. are tallied by inch classes.

Board measure based on trees 12 inches and over in diameter.

DATA SERIES VI—(*Continued*)

STATISTICS OF SAMPLE ACRE PLOTS IN PURE EVEN-AGED STANDS OF DOUGLAS FIR

Data collected by the U. S. Forest Service, 1909 and 1911, in Western Washington and Oregon.*

SITE QUALITY II

Location and Plot Number	No. of Trees	Age of Stand, Years	Volume		Basal Area, Square Feet	D.B.H. of Average Tree, Inches	Height of Average Tree, Feet
			Cubic Feet	Feet, B.M.			
Marmot, Ore.							
308	208	41	6,101.5	15,429	169.1	12.2	93
307	257	41	5,750.0	15,476	159.0	10.7	89
306	236	41	4,979.0	11,812	138.0	10.3	86
305	235	41	6,376.0	19,485	172.0	11.6	91
304	252	41	6,373.0	18,360	173.0	11.2	90
303	184	41	6,484.0	21,953	170.0	13.0	96
302	215	41	6,433.0	21,233	171.0	12.0	92
Morton, Wash.							
262	254	50	6,334.2	19,442	156.06	10.6	93
261	264	50	7,108.8	21,331	181.73	11.3	97
260	222	50	7,728.8	29,277	195.43	12.7	103
Huckleberry Mt., Oregon N. F.							
293	448	57	6,747.8	12,742	207.04	9.2	78
292	400	57	8,909.8	27,894	255.15	10.8	85
291	582	57	8,674.8	17,218	272.00	9.3	78
290	412	57	8,650.4	25,750	249.08	10.6	84
Santiam N. F., Minto Trail							
123	305	98	10,380.0	44,055	242.0	12.0	102
112	212	98	13,108.0	64,428	292.0	15.9	119
118	277	98	12,970.0	62,240	295.0	14.0	111
117	295	98	13,351.0	61,142	304.0	13.8	110
116	261	98	12,327.0	57,640	280.0	14.0	111
114	228	98	14,842.0	75,103	333.0	16.3	120
122	183	98	12,482.0	65,699	294.0	17.1	123
Columbia N. F. Racetrack Trail							
21	250	119	15,433.4	64,230	319.54	15.3	127
22	190	119	14,879.5	68,608	302.33	17.1	132
23	269	119	15,355.1	65,206	330.45	15.0	126
24	278	119	14,764.6	64,302	325.54	14.6	125

* This table includes all species on the acre plot except cedar. The latter is considered an understory. Douglas fir is the predominating species, with scattering hemlock, firs, spruce, pines and hardwoods. All trees to 2 inches D.B.H. are tallied by inch classes.

Board measure based on trees 12 inches and over in diameter.

DATA SERIES VI—(*Continued*)

STATISTICS OF SAMPLE ACRE PLOTS IN PURE EVEN-AGED STANDS OF DOUGLAS FIR

Data collected by the U. S. Forest Service, 1909 and 1911, in Western Washington and Oregon.*

SITE QUALITY III

Location and Plot Number	No. of Trees	Age of Stand, Years	Volume, Cubic Feet	Volume, Feet, B.M.	Basal Area, Square Feet	D.B.H. of Average Tree, Inches	Height of Average Tree, Feet
Humphrey, Wash.							
235	306	57	6,845.3	20,383	209.56	11.2	80
236	292	57	7,635.3	25,630	229.80	11.9	82
237	385	57	7,173.4	15,017	203.41	9.9	75
238	520	57	5,946.4	8,065	198.62	8.3	67
239	481	57	6,128.0	9,005	203.79	8.8	70
240	524	57	5,596.5	7,502	190.52	8.1	66
241	537	57	6,379.3	7,268	214.57	8.6	69
242	587	57	5,887.1	4,719	202.77	8.9	71
243	635	57	5,260.9	3,169	190.49	7.4	63
244	505	57	5,862.8	8,452	186.28	8.2	67
246	741	57	5,029.2	3,311	158.47	6.2	56
Morton, Wash., Randle Road							
253	574	58	6,131.0	11,346	176.38	7.5	74
254	431	58	8,272.2	22,558	218.97	9.7	86
255	814	58	6,092.0	8,984	184.54	6.2	66
Columbia N. F., Racetrack Trail							
2	138	70	5,282.0	21,201	130.00	13.1	97
3	201	70	7,488.0	30,127	184.00	13.0	97
6	196	70	9,790.0	42,071	240.00	14.3	102
Columbia N. F., Huckleberry Mt.							
30	133	97	9,046.0	37,032	205.00	16.8	123
29	146	97	10,435.0	42,160	234.00	17.7	128
31	130	97	7,743.0	34,137	182.00	16.0	118
32	143	97	11,326.0	45,555	247.00	17.8	128
33	134	97	10,074.0	41,064	222.00	17.4	126
38	179	97	8,740.0	29,935	191.00	14.0	103
39	179	97	11,775.0	47,922	261.00	13.1	98
40	145	97	10,480.0	42,210	230.00	17.0	124
41	164	97	10,358.0	41,108	235.00	16.2	119
Frank Brice Cr., Ore.							
145	158	120	9,127.0	44,507	191.00	14.9	124
144	133	120	12,327.0	64,703	243.00	18.3	134
135	149	120	7,649.0	31,596	155.00	13.8	119
138	105	120	6,742.0	35,762	145.00	15.9	127
137	176	120	8,825.0	45,524	176.00	13.6	119
139	137	120	10,987.0	53,522	215.00	16.9	130

* This table includes all species on the acre plot except cedar. The latter is considered an understory. Douglas fir is the predominating species, with scattering hemlock, firs, spruce, pines and hardwoods. All trees to 2 inches D.B.H. are tallied by inch classes.

Board measure based on trees 12 inches and over in diameter.